

Casualty Evacuation in the Contemporary Operating Environment

**A Monograph
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Abstract

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CHAPTER ONE

INTRODUCTION

In the past few years, the United States Army has taken deliberate steps to appropriately assess threats and better understand the operating environment in order to develop an effective future military force. For 45 years, the Cold War had presented a constant possibility of worldwide conflict, probably centered in central Europe. The end of the Cold War of course eliminated the long held threat of a huge global war with the Soviet Union, but no great peace has replaced the threat. The ensuing environment has been characterized by varying degrees of regional confrontation and instability, with great uncertainty about the future development of more formidable and direct threats to US security.

Regional instabilities, characterized by transnational, religious, ethnic, and tribal interests provide a complex backdrop to the world environment. Technological innovations and distribution of Soviet weapons and scientific knowledge provide lethal potential to virtually any military in the world. Many other factors continue to influence the environment. Global population growth is more rapid than ever. Time and distance factors over the earth continue to shrink. The information revolution forges global economies while at the same time influencing perceived relative deprivation among those societies of lesser fortune.

Potential adversaries in this the new or contemporary operating environment continue to study the United States as the only remaining superpower. The past decade of intervention activities from the US have followed a very distinguishable and predictable model: gradual build up of combat forces to a forward base of operation, and offensive action only after overwhelming combat and sustainment power is massed. While the US power projection capability remains unmatched in the world, lack of capability to act immediately in a crisis situation creates opportunity for the enemy.

Future adversaries will be highly flexible and adaptive people. They will not meet the United States head on in a showdown of precision warfare. They know America's vulnerabilities and will counter American strengths using deception, concealment, and information operations to their advantage.

This new environment plays a huge role in shaping America's future military force. To ensure combat effectiveness to dominate evolving sophisticated threats, the Army must adapt its capabilities and employ effective warfighting concepts. Shaping the evolving logistics capabilities to meet the needs of the future Army is an enormously complex undertaking. Combat and logistics capability are inseparable, for while the needs of combat set logistics requirements, the limits of logistics constrain combat. As always, the importance of desired combat capabilities must be weighed against their logistics implications and costs.

The enemy of the future is expected to seek to deter or preclude US involvement in his region, even if only temporarily, in order to achieve his objectives. In doing so, this enemy will attempt to exploit perceived US vulnerabilities such as a predictable and observable military deployment, or lack of national will, in order to preclude or marginalize US involvement in regional conflict.

One major area of perceived vulnerabilities includes risk aversion, and Americans' unwillingness to accept heavy losses. In the 20th Century, 35 million soldiers died in warfare; Americans numbered over a million.¹ Throughout history, societies have struggled to balance the necessity to wage war with the horrifying costs that war entails. As societies and knowledge have progressed, so too have efforts to protect and sustain human life on the battlefield.

Analysis of past experience concerning friendly casualties, indicates approximately 65% of the US casualties who die in combat do so immediately or within 5 minutes, and are therefore not salvageable.² Although a number of the remaining 35% will probably not live either, at least some of those are salvageable.³ Considering that most of those who die, simply bleed to death, and that many of those live for at least 5 minutes, effort to salvage lives on the battlefield might be most productive if focused upon immediate actions that save lives. Emergency medical treatment personnel understand that most

¹ For world-wide figures, See, White, Mathew, *Bloodiest Wars of the 20th Century*, A compilation of Statistics, Gathered from Various Sources, internet, Last updated, January, 1999. <http://users.erols.com/mwhite28/war-list.htm> For American numbers, see, Department of Defense, Washington Headquarters Service; Director for Information Operations Reports. Principal Wars in which the United States Participated.

² Ronald F. Bellamy, *The Causes of Death in Conventional Land Warfare: Implications for Combat Casualty Care Research*. Military Medicine 149: 55-62, 1984.

³ Ibid.

traumatic injuries allow very little time for medical heroes to undo the downward spiral of life-threatening damage incurred as a result of the injury. Civilian and military medical professionals refer to that critical period available for potentially life saving intervention as the “golden hour.”⁴ If appropriate immediate actions are taken within that time, many casualties would not die, but would make their way to a treatment facility for definitive care required to start the body’s healing process and see them through to recovery.

As with civilian medical conditions, most combat fatalities occur primarily as a result of blood loss.⁵ On the combat battlefield, however, the brutality of the injuries, and the fact that critical injuries are very often inflicted in multiples upon a single victim, reduces a casualty soldier’s golden hour to something much less than a whole hour.⁶ Casualties with multiple wounds affecting more than one organ are more difficult to treat because of synergistic traumatic injury effects. Blood loss is multiplied; shock is more likely, more severe, and more lethal.⁷

The Army’s medical evacuation system is a continuum from the forward line of troops through the continental United States base. Casualty evacuation is the timely, efficient movement *and en route care* of sick or injured persons from the battlefield to a medical treatment facility.⁸ If the nature of the war allows, as did major wars of the previous century, the United States can position sophisticated medical facilities very near the wounded soldier. In light of the exceedingly unfavorable circumstances of war, casualty movement between echelons in forward areas is usually accomplished within a matter of hours.

⁴The phenomenon of the golden hour was first observed and recorded by doctors serving in the Korean War. The phenomenon is tied to the process of dying, where by a human’s living cells die, causing respective organs and systems to malfunction. The general understanding of the golden hour within the medical community is that the process of dying, usually triggered by blood loss after a traumatic injury must be successfully intervened within one hour of occurrence to save the victim’s life.

⁵ Dr. Howard Champion at the annual AMEDD conference Summer 2000.

⁶ Average time is debatable, and actual individual case time varies with wounds, individual health and will to live, and other biological factors.

⁷ Emergency War Surgery NATO Handbook: Part I: Types of Wounds and Injuries: Chapter VIII: Multiple Injuries; p 1. <http://www.vnh.org/EWSurg/ch08/08Introduction.html>. Accessed 23 Jan 02.

⁸ FM 8-10-6; emphasis added.

As alluded to earlier, the conduct of modern warfare is changing. The battlefield of the future will be broader, deeper, more fluid, more destructive, and more resource hungry.⁹ Resource-intensive facilities that are staffed to provide extensive care will, of tactical necessity, be deployed considerably further to the rear. The concepts of phased wound management and initial and reparative surgery will certainly persist, but distances will increase significantly between echelons of care, as well as between providers within echelons. On a highly mobile battlefield, initial wound surgery may have to be performed very far forward under extremely austere, even primitive, conditions within enveloped enclaves.¹⁰ Medical teams carrying their equipment in rucksacks on their backs may be tasked to perform only that emergency life-saving treatment that will allow the casualty to survive transportation to a higher level of medical care.

The evacuation system is designed to return to duty the maximum number of combat soldiers at the lowest possible level, in order to preserve combat power. In this manner, the system serves as the primary source of trained replacements during the early stages of a major conflict.¹¹ Caring for wounded soldiers is not merely an attempt to preserve a limited resource, however, but an obvious reflection of American culture and the value Americans associate with human life.¹²

At the tactical level, executing effective casualty evacuation preserves fighting strength while building confidence in our soldiers and morale in our units. It follows that commanders confident in their casualty evacuation capability maintain greater flexibility in the manner they employ their units.¹³ Demonstrating proficiency in saving soldiers' lives also creates confidence in the American public, and sustains national support for our military endeavors. Saving lives on the battlefield is therefore a critical consideration in building the Army of the future.

Peacetime training history at the tactical level indicates, however, raises concern as to whether the Army is well prepared in saving those precious lives. Combat Training Center trends show that most

⁹ US Army White Paper, Concepts for the Objective Force.

¹⁰ Emergency War Surgery NATO Handbook: Introduction.

<http://www.vnh.org/EWSurg/ch08/08Introduction.html>. Accessed 23 Jan 02.

¹¹ FM 8-10-6, 1-3.

¹² George Santayana, *Life of Reason*, "Reason in Common Sense," 1906

companies typically average 53 percent “died of wounds” (DOW) rates.¹⁴ This means that 53 percent of a unit’s casualties die from their wounds before they receive proper medical treatment. Most of the training center observer/controllers state that the primary cause for this high mortality rate is that units take too long to evacuate casualties. Commanders struggle with immediate follow on missions because the replacement system cannot keep pace with the casualty rates.

Moreover, soldiers in the unit lose faith in the casualty evacuation system. They begin to believe that if they are wounded on the battlefield they have little chance of survival. Although it is only a training environment, leaders as well as peers awaken to the agonizing sadness and depression associated with the loss of their soldiers. This training environment DOW rate is even more discouraging when you know that most of the casualties are within 10 kilometers of the supporting medical company and a medical physician.¹⁵

Nonlinear battlefields of the future may present commanders with constraints beyond their control that preclude traditional casualty management. Temporary pauses in local air superiority may deny aero medical evacuation from forward areas. Tactical encirclement or weather may compel a forward maneuver element to hold wounded soldiers. Battalion surgeons or physician assistants may find themselves in a position where they are denied the option of moving casualties to definitive care facilities.

The objective of this monograph is to determine whether the Army’s casualty evacuation system is adequate to support soldiers in future combat. Research indicates the high DOW rates result primarily from the units’ difficulties in efficiently evacuating soldiers.¹⁶ Medical wisdom suggests that lives are saved or lost as a result of actions taken within the “golden hour” following a potentially fatal injury.

¹³ Casualty aversion studies indicate in fact that it is neither the American people or politicians but senior military officials who are most unwilling to accept losses.

¹⁴ Matson, Steven Bennett, Betty Medical Evacuation: Clearing the Mechanized Battlefield, CMTC; CALL Newsletter 99-13. A number of reasons could explain CTC DOW rates as artificially high. This reference is not to emphasize the rates but the inherent difficulty in medical evacuation. These rates are not indicative of expected rates in combat.

¹⁵ Ibid.

¹⁶ Ibid.

To assess the adequacy of the Army's casualty evacuation system, this monograph examines the nature and unique characteristics of expected combat casualty wounds and published combat health support doctrine. The paper further provides information on emerging medical technologies applicable to the discussion of traumatic injury, and respective medical care. The following closely related criteria are considered in analysis of these aspects of the system:

Responsiveness: Responsiveness is the crucial characteristic of combat service support.¹⁷

Responsiveness is the foundation of effective medical support. Responsiveness entails providing the right support in the right place at the right time, and relies on the ability to foresee requirements. It involves identifying, accumulating, and maintaining the minimum assets, capabilities, and information necessary to meet support requirements.¹⁸

Continuity: Continuity is closely related to responsiveness. In casualty care and treatment, continuity is achieved by providing optimum care and treatment to casualties in an uninterrupted manner. This aspect of medical care includes moving casualties through a progressively more capable medical treatment system, extending from the forward area of the combat zone to the area as far rearward as the patient's condition requires, possibly to the continental United States (CONUS).¹⁹ Combat health support must be continuous since an interruption of treatment may cause an increase in morbidity and mortality.²⁰

Flexibility: Flexibility is the extent to which the system lends itself to adaptation to meet the requirements of changing situations or missions. Flexibility is closely related to, and enhances the fundamental aspect of responsiveness and continuity. The objective of flexibility is to be prepared to shift medical support resources to meet changing requirements. Changes in tactical plans or operations make flexibility in combat health support essential. Medical units are not held in reserve.

Medical treatment at echelon II provides immediate lifesaving measures, emergency care, and resuscitation procedures. Therefore, this monograph focuses at the lowest levels of medical treatment,

¹⁷ FM 3-0, 12-3.

¹⁸ Ibid.

¹⁹ FM 8-10, 1-14.

²⁰ FM 4-02. Headquarters, Department of the Army, Washington, DC, 15 November 2000.

from the point of injury to echelon II medical treatment. Secondly, the paper is focused toward treatment methods and techniques as opposed to transfer of casualties through the system.

Chapter two of this monograph provides foundational analysis concerning the significance of battle casualties. This chapter explores the statistical analysis gleaned from historical studies, and illustrates basic biological science associated with traumatic injury and the ensuing process of dying as a result of injury. The chapter then introduces accepted medical philosophy that establishes treatment protocol for intervention to save lives on the battlefield.

The next chapter discusses current Army medical doctrine as applied to combat health support and its application on the battlefield. A fourth chapter is devoted to emerging medical technologies and biomedical advances that might be incorporated in future doctrinal concepts to save lives and better care for combat casualties in modern and future conflicts.

The final chapter of the monograph assess the adequacy of the casualty evacuation system utilizing the criteria stated above and discusses conclusions and recommendations. Included in the final chapter are a few issues that require further study or exploration.

CHAPTER TWO

COMBAT CASUALTIES

In any group of combat casualties, some will be so seriously injured that death is almost instantaneous; others are likely to live with very little or no medical care at all. Medical experts and historians have estimated that approximately 65 percent of combat casualties who die, do so immediately or within 5 minutes of their injury and are not salvageable.²¹ Though precise data are not available to verify statistics regarding the potentially salvageable casualties.²² Without treatment, an additional 15% die within 30 minutes from injuries of the head, neck, chest, or abdomen. The remaining 20% die after 24 hours sometimes due to a combination of prolonged hypo-volaemia and sepsis; deaths from infective complications of the wound alone occur after a few days.²³

The Golden Hour

Future military operations will involve dispersed, independent units located far from friendly medical care facilities. The time, people, and facilities available to care for casualties will be severely limited. This situation will be particularly serious given the narrow window of opportunity available to care for serious wounds and injuries.

Historically, about 20% of all injured soldiers die in battle, and 90% of those die before they are treated in a medical facility.²⁴ To salvage any of those casualties, medical care must be administered immediately, and appropriately. Roughly 80 percent of deaths in military operations occur in the first 30 minutes,²⁵ when often the only care available comes only from the casualty victim, a buddy or combat medic.

The process of dying after a traumatic injury has been described as premier shock trauma, the irreversible uncoupling of bodily functions. This uncoupling is the result of blood loss after injury. Both

²¹ Ronald Bellamy, Causes of Death in Conventional Land Warfare.

²² Bowen, and Bellamy, Emergency War Surgery, Combat Casualty Overview.1998.

²³ Ronald Bellamy, Combat Trauma Overview, in Textbook of Military Medicine, Volume4

²⁴ Ibid.

²⁵ Bellamy, Combat Wounds Ballistics, 1987. The study of wound ballistics attempts to predict and to analyze the damage that will be sustained by the different tissue types when struck by missiles of varying sizes, shapes, weights, and velocities.

the volume reduction and blood pressure contribute to oxygen starving in the tissues. Organs then malfunction and whole systems begin shutting down. The victim's heart continues to pump in an effort to feed the body's tissues. Even as the heart pumps faster and faster the blood loss continues, and the damage to tissues cannot be reversed. In a very short time, the entire body stops functioning. Medical wisdom refers to this urgent period of time as the "golden hour."

The golden hour concept began during the Korean War. Doctors noticed that soldiers' survival rates improved greatly if they were treated within an hour after being wounded. One of those doctors was R. Adams Cowley, who had served during World War II. Dr. Cowley conducted extensive research regarding these observations in the 1970's, and was the first to actually coin the golden hour phrase in the medical context.²⁶ Dr. Cowley described the premier shock trauma process and said that if the process were intervened within an hour the patient could live. Otherwise the process was irreversible, and the patient died.

The golden hour has become an integral part of medical treatment philosophy, and its concept now extends to many other causes of death. Doctors have begun using the golden hour phrase with stroke victims, and heart failure, etc. Use of the golden hour phrase, of course, implies opportunity. The terms accentuate the hope for life, and encouragement to those trying to save lives.

Battlefield Injuries

As stated earlier, a wounded combat soldier's golden opportunity for life is normally reduced significantly, though actual averages can be debated, and individual time frames depend on a number of factors. This reduction in available intervention time can be explained in part due to the lethality of modern weapons and convention that often a soldier casualty has multiple traumatic injuries. More blood is lost more quickly, and damage to tissues begins right away.

Potentially salvageable casualties might be considered in two large groups: those who, without intervention, would die within 30 minutes and those who die after. Early deaths may be prevented by

²⁶ Biography, as stated on line, <http://www.logophilia.com/WordSpy/goldenhour.asp>; See also, <http://www.arlingtoncemetery.com/racowley.htm>

airway protection, fluid resuscitation, arrest of accessible hemorrhage, and tube thoracostomy; later deaths may be avoided by prevention of infective complications by antibiotics, wound excision and corrective amputation.²⁷

Major combat wounds initiate sudden and intense physiological and metabolic responses. The magnitude and duration of the response are proportional to the extent of injury and the interval between wounding and treatment. Typical response is characterized by progressive circulatory insufficiency, decreasing cardiac output, decreasing oxygen consumption, and developing acidosis.²⁸ Without adequate resuscitation, the patient often suffers post-traumatic complications as indicated by increase in oxygen consumption, tachycardia, and negative nitrogen balance with depletion of lean body mass.²⁹

Early loss of less than 10 percent of the circulating blood volume may be associated with no change in arterial pressure because of compensatory increases in sympathetic nervous system activity as well as arterial and venous constrictions initiated by feedback loops inspired by low-pressure cardiac receptors.³⁰ Further losses of blood volume and pressure cause increased sympathetic nervous reactions to the heart and arterial vessels. Tissue injury as a result of prolonged ischemia leads to cellular membrane collapse that destroys life essential balances of chemicals.³¹

Post-traumatic complications also influence the duration and magnitude of the body's on-going response. Combat wounds are characterized by lacerated, contused, and devitalized tissue; contaminated blood; disruption of the local blood supply; presence of foreign bodies; and contamination with various microorganisms, all of which may lead to the development of complicated subsequent infection. The devitalized tissue and blood provide an excellent culture medium to support the growth of microorganisms, and thus are conducive to the development of wound infections.³²

²⁷ Department of the Army, Office of The Surgeon General; *Military Psychiatry: Preparing In Peace for War*, The Textbook of Military Medicine, Part I, Warfare Weaponry and the Casualty, 1994.

²⁸ Berne, *Physiological Responses to Hemorrhage*, Physiology, St. Louise 1983. p 148.

²⁹ Ibid.

³⁰ Chien, S, *The Role of Sympathetic Nerve system in Hemorrhage*. Physiology Review, 1967. 47, p214.

³¹ Lefer, AM. *Eicosinoids as Mediators in Ischemia and Shock*. Journal of Surgical Research, 1985, 42, p1-6.

³² Ibid.

Injury-related edema can produce tension within a fascial compartment that compromises the capillary circulation of the tissues within the compartment. In turn, the low volume capillary circulation induces local tissue anoxia.³³ Additionally, the anaerobic character of hypoxic tissue may inhibit function of leukocytes.³⁴ The time lag between wounding and treatment represents an incubation period during which bacteria may proliferate and initiate infection. Early adequate surgery is therefore the most important step in prophylaxis against wound infection. A wound debrided of nonviable contaminated tissue and left with an excellent blood supply, is best able to resist infection.

Battlefield Treatment

As mentioned above, statistically some casualties are expected to die almost immediately, but approximately 35% of all casualties that died as a result of combat injury in the past were at least potentially salvageable.³⁵ To improve survival rates for that population of casualties, we must consider causes of death and appropriate life-saving treatment. Statistically, the single major cause of death on the battlefield is hemorrhage;³⁶ and the best opportunities for salvaging those casualties is fluid resuscitation, and treatment for long-term effects of hypovolemia.³⁷ There are slight numbers of other casualties however, such as the few who die from asphyxiation, that are part of the expected salvageable group. Emergency treatment for these other causes of death must also be considered. In this manner, it is reasonable to expect that immediate and appropriate medical care might save a significant number of lives on the battlefield.

Airway Management

The breathing process allows the lungs to draw oxygen from the air and put it into the blood. The heart then pumps the blood through the body to be used by living cells. Without oxygen, cells die; brain cells

³³ Mosby's Medical Dictionary, Revised 3rd Edition, 1990. p 70.

³⁴ Ibid.

³⁵ It should be noted that Bellamy's conservative estimates are closer to 20% salvageable: some 10% within 30 minutes and 10% later.

³⁶ Ronald Bellamy, Combat Trauma Overview, in Textbook of Military Medicine, Volume 4

³⁷ NATO Handbook of Emergency War Surgery

die within 4 to 6 minutes. This could result in permanent brain damage, paralysis, or death.³⁸ Airway management to allow free flow of oxygen into the lungs is therefore critical in beginning the lifesaving process.

The first step of treatment for a casualty is to ensure the airway is clear. If a casualty is conscious and breathing, then airway intervention is not necessary. Clearing the airway is necessary and critical if the soldier is not conscious, or has labored breathing. First approaches include simple chin lift, jaw thrust, and finger sweeping the casualties throat for obstructions.³⁹ If the casualty does not resume breathing after the airway is cleared, he will require artificial respiration either by mechanical device, or mouth-to-mouth resuscitation.

During anesthesia, upper airway collapse associated with the induced loss of muscle tone is a distinct possibility. In this case, the medical care provider must simultaneously elevate the jaw while pressing backwards against the face to open the airway. Usually, insertion of an artificial airway is required to bypass obstruction of the airway by the tongue.⁴⁰

Clearing the airway and initiating responsive breathing cannot be overemphasized. Two studies examining pre-hospital deaths from trauma in the United Kingdom have shown significant morbidity and mortality from airway obstruction that went untreated by ambulance crews or first responders.⁴¹ Hussain and Redmond concluded that up to 85% of patients who die with survivable injuries before reaching hospital may do so because of airway obstruction. In another study, airway obstruction was thought to have contributed to death from major trauma in 28% of patients treated by ambulance crew.⁴² Opening

³⁸ Charles E Silva; *Lifesaving and Water Safety Today*, Springfield, Associated Press, 1965. p128-129

³⁹ Ibid.

⁴⁰ NATO Handbook of Emergency Surgery

⁴¹ Hussain and Redmond,

⁴² Civilian studies and military medicine have complemented one another in the progress of medicine in general. The second study found specifically that difficulties of airway management are exacerbated by poor lighting; a difficult patient position; blood, vomit, and debris in the upper airway; and poor views with laryngoscopes due to stabilization of the spine.

the airway is so critical that even additional trauma incurred from attempting thoracostomy will not likely to worsen the patient's condition,⁴³ and must be attempted when all other methods fail.

Any respiratory distress occurring from a penetrating chest wound is probably tension pneumothorax, a potentially fatal condition wherein a lung collapses due to abnormal balance of pressure within and without.⁴⁴ Technically, tension pneumothorax exists when the pleura cavity pressure equals or exceeds atmospheric pressure. Any type of puncture wound can create a valve-like opening that allow alveolar air to leak into the pleural space. This one directional passage lets air in during each inspiration, but little or no air passes back during expiration.⁴⁵ Pressure continues to build, collapsing the lung toward the center of the chest, and displacing the heart and great vessels to the opposite side of the chest.⁴⁶

Tension pneumothorax does not always require immediate emergency treatment, and the casualty can wait for intervention at a hospital. If immediate intervention is necessary, the simplest method is to insert a needle into the pleural space to create an opening to relieve intrapleural pressure, and relieve the trauma caused by mediastinal shift of organs in the chest cavity.⁴⁷

Similarly, a tearing type penetration that does not seal itself off, causes a sucking chest wound. Characteristic sucking sounds come from the chest area as air is "sucked" into the chest cavity from outside. Sucking wounds are potentially the most dangerous type of chest wound because air admitted from the outside of the chest goes not into the lung, but into the space between the lungs and the chest wall.⁴⁸

Soldiers train to provide buddy aide for sucking chest wounds by applying a large thick compression dressing to the wound. The appropriate technique calls for the dressing to have some type of sealant, such as the plastic wrapper from the dressing itself, and to emplace the bandage during the exhalation phase.⁴⁹

⁴³ Cameron and colleagues, *Helicopter Retrieval of Primary Trauma Patients by Paramedic Helicopter Service*, Australian and New Zealand Journal of Surgery, 1993. See also, John Henderson, *Emergency Medical Guide*, and Crosby and Lewallen, *Emergency Care and Transportation*.

⁴⁴ John Henderson, *Emergency Medical Guide*, 4th Edition. McGraw-Hill Book Company. 1978

⁴⁵ Ibid.

⁴⁶ Black's Medical Dictionary, 36th Edition, p 542

⁴⁷ John Henderson, *Emergency Medical Guide*, 4th Edition. McGraw-Hill Book Company. 1978.

⁴⁸ Ibid.

⁴⁹ Common Task Training for Soldiers,

Multiple puncture wounds or broken ribs require wrapping the entire chest cavity with wide strips of bandage gauze or adhesive tape to prevent ballooning.

Circulation

The human circulatory system, made up of the heart, blood and blood vessels, is quite complex. Though the system is normally quite reliable and resilient, its malfunction is debilitating. The healthy human heart, under normal conditions beats approximately 70 times each minute, sending two and a half to four liters of blood coursing through hundreds of thousands of vessels.⁵⁰ Exquisitely coordinated electrical timing of millions of heart cells sparks the heart to pump in a rhythmic, efficient fashion.⁵¹ When that coordination is disrupted, life-threatening ventricular arrhythmias result.⁵²

Ventricular arrhythmias occur when a group of heart cells in the ventricles triggers contractions out of sync with the normal rhythm.⁵³ A number of factors can prompt a ventricular arrhythmia, including stress, exercise, caffeine, tobacco, and several other chemicals.

Ventricular arrhythmias commonly occur due to some interference within the mechanism controlling heartbeat.⁵⁴ These interferences may arise when the body is under severe physical stress, from such problems as lack of oxygen, very low blood pressure, or major blood loss,⁵⁵ (as experienced with typical combat wounds.) Arrhythmias may also be triggered by surgery, or other conditions that cause abnormal blood and tissue concentrations of potassium, magnesium, sodium, or calcium, minerals that play key roles in stimulating electrical impulses in the heart.⁵⁶

Ventricular tachycardia is regular, but rapid heartbeat that arises from the lower chambers of the heart. It is much faster than the normal heart rate of 60 to 100 times per minute, normally experienced with

⁵⁰ Mosby's Medical Dictionary, p 202.

⁵¹ Stephen Goldberg, M.D., *Clinical Physiology Made Ridiculously Simple*, 2001.

⁵² Ibid. See also Gerard J. Tortora and Sandra Reynolds, *Principles of Anatomy and Physiology, 9th Edition* John Wiley & Sons, New York, 1999.

⁵³ Ibid.

⁵⁴ Black's Medical Dictionary, 36th Edition, p 55.

⁵⁵ Ibid.

⁵⁶ Stephen Goldberg, M.D., *Clinical Physiology Made Ridiculously Simple*, 2001.

congestive heart failure, hemorrhage or shock.⁵⁷ Tachycardia is the heart's attempt to increase the amount of oxygen delivered to the cells by increasing the amount of blood circulated.⁵⁸ Tachycardia prevents ventricles from properly filling with blood, and reduces the heart's pumping efficiency.

Ventricular tachycardia can degenerate into ventricular fibrillation, which is an extremely rapid, chaotic rhythm that causes the heart to quiver. Such quivering prevents the heart from pumping blood to the rest of the body. The onset of a ventricular fibrillation is dramatic: victims suddenly lose consciousness and collapse. Their pulse, heartbeat and blood pressure fall to zero, and death occurs within four minutes⁵⁹ without effective treatment.

Casualties suffering severe ventricular tachycardia or ventricular fibrillation must be treated immediately with defibrillation and ventilation.⁶⁰ Effective defibrillation synchronizes the heart's electrical system. The shock normally starts the heart back into a regular beat.

Most casualties who die on the battlefield, simply bleed to death. As mentioned previously, the human body reacts in a number of ways attempting to compensate the blood loss. As blood volume is lost, blood pressure is also reduced and oxygenation of tissues is increasingly difficult. As discussed above, tachycardia is the body's attempt to overcome the shortage of oxygen by increasing the heart rate. Wounds must be effectively closed to accomplish hemostasis, cessation of the casualty's bleeding. Achieving hemostasis is critical in implementing any attempt to resuscitate a casualty. Failure to completely close even surgical wounds can result in serious or possibly life-threatening complications, including blood loss, tissue damage, infection and excessive scarring.

Normal protocol for stopping bleeding in combat casualties is to apply simple gauze bandages to tissue injury sites and apply pressure to the site to stop the vascular blood flow. When extreme blood loss is occurring from arterial rupture, a tourniquet may be applied. Sutures have traditionally been the most common method of closing wounds. Sutures mechanically bring together the tissues on either side of a

⁵⁷ Mosby's Medical Dictionary, p1147.

⁵⁸ Ibid.

⁵⁹ Mosby's Medical Dictionary, p1231.

⁶⁰ Ibid. Defibrillation delivers direct electrical countershock to terminate ventricle fibrillation.

wound to facilitate healing. In the 1960s, surgical stapling was introduced to reduce the time-consuming and cumbersome aspects of suturing. Surgical staples also draw together tissue along the line of incision. Both methods are effective at closing the wound, and normally assist healing by preventing infection. Neither suturing nor stapling, however, have inherent sealing capabilities and thus cannot always eliminate bleeding along suture lines.

Under normal circumstances, blood maintains its fluidity because of balancing effects of procoagulants and anticoagulants from circulation factors such as interactions at the blood-endothelium interface.⁶¹ Coagulation mechanisms assist hemostasis and allow microcirculation without progression to systemic traumatic injury reaction. Once blood has coagulated at the wound site, a system of fibrinolysis can reestablish blood vessel function, and white blood cells continue to circulate normally, initiating healing processes. Once healing occurs, degradation of coagulants in the injured area ensues.⁶²

Resuscitation

Once the airway is opened, respiration has begun, heart rate is at least somewhat controlled and hemostasis has been achieved, the casualty may require further resuscitation to regain blood volume and blood pressure. These steps are necessary to nourish tissues suffering from oxygen starvation.

Lactated Ringer's solution is most commonly the fluid administered to add volume to the blood stream, even if bleeding has not completely stopped. Sidney Ringer was a British physiologist, who gradually perfected perfusion techniques by proving that if small amounts of potassium are added to the normal solution of sodium chloride, isolated organs can be kept functional for long periods of time.⁶³ Eventually Dr. Ringer obtained a suitable physiological saline solution that would keep the heart beating outside of the body. Ringer's solution became an immediate necessity for the physiological laboratory.

Ringer's isotonic electrolytic solution contain specific amounts of sodium, potassium, calcium, and magnesium chlorides; sodium bicarbonate, dextrose, and water, and is widely used as a universal infusion

⁶¹ Pearson, Blood 1994.

⁶² Ibid.

⁶³ <http://www-ncmir.ucsd.edu/doc/labmanual/ringer.html>

solution.⁶⁴ Ordinarily a shock casualty receives 1,000-2,000 cc (one to two liters) of lactated Ringer's solution, infused as rapidly as possible.⁶⁵ Some casualties respond promptly and remain stable with only this replacement fluid therapy. If hemorrhage has been severe or is ongoing, the response will usually be only transient, but nevertheless allow time for typing and cross matching of blood required for a transfusion.⁶⁶ Lactated Ringer's solution, in addition to providing a rapid increase in circulating volume, will begin correcting low extracellular volume space resulting from compensatory fluid shifts induced by the shock state.⁶⁷

Crystalloid solution rapidly equilibrates between the intravascular and interstitial compartments. Therefore, adequate restoration of hemostatic stability may require large volumes of Lactated Ringer's solution.⁶⁸ It has been empirically observed that approximately 300 cc of crystalloid is required to compensate for each 100 cc of blood loss.⁶⁹ This 3:1 rule is a good beginning point for fluid resuscitation, but obviously is not a hard and fast rule for those with massive hemorrhage. If the 3:1 ratio were adhered to in a casualty requiring 5,000 cc of blood replacement, inundation would result. About 3,000-4,000 cc of Ringer's lactate seems reasonable.⁷⁰

Blood is one of the world's most vital medical commodities, saving millions of lives every year. Spun in a centrifuge, it divides into layers--red cells on the bottom, a thin intermediary layer of platelets and white cells, and an upper tea-colored layer of plasma. Each layer, in turn, can be used as various therapeutic products. Red cells can be transfused directly. White cells and platelets can be used to restore resistance or clotting ability to patients undergoing chemotherapy. Plasma, a resource in its own right, yields albumin for restoring circulation, clotting factors for patients with hemophilia, antibodies for vaccine production, and several other reagents and pharmaceuticals.⁷¹

⁶⁴ Mosby's Medical Dictionary, p1038.

⁶⁵ NATO Handbook of Emergency War Surgery

⁶⁶ Ibid.

⁶⁷ Ibid.

⁶⁸ Ibid.

⁶⁹ Sydney Ringer: Regarding the Action of Hydrate of Soda, Hydrate of Ammonia, and Hydrate of Potash on the Ventricle of the Frog's Heart. Journal of Physiology, Cambridge, 1880-1882, Volume 3: 195-202.

⁷⁰ NATO Handbook of Emergency War Surgery.

⁷¹ Douglas Starr, *Blood: an Epic History of Medicine and Commerce*, New York, Alfred A. Knopf, Inc. 1998.

Blood transfusion is an integral part of resuscitating casualties suffering extreme hemorrhage or continuing hemorrhage. Transfusion may take place as the only resuscitative measure or in conjunction with administration of Ringer's solution or other fluid. Whole blood is preferred because of its physically compatible characteristics, faster infusibility and often retained clotting factors.⁷² Ideally, the casualty should receive type-specific, cross-matched blood.⁷³ The United States forces in Vietnam habitually practiced type-specific blood transfusion.⁷⁴

During the Korean conflict, the practice of transfusing type O, low-Rh titer blood was used.⁷⁵ Type O blood may be administered without counter reactions, to all other blood types. It is the most commonly available on the battlefield, and is most often used when type matching is not available. When a more forward echelon of care has already infused type O blood, the higher echelon continues care with type O. Switching to type-specific blood, especially after several units of type O blood have been given, can result in a transfusion reaction. Experts recommend that type-specific blood be withheld for 2-3 weeks or longer if the casualty initially receives more than four units of type O.⁷⁶

When blood resources are limited, and type matching will assist in stretching blood supplies, a type change warrants consideration. As a general rule, if four units or less of low-titer O blood have been given, a change to type-specific blood is possible without producing ill effects.⁷⁷ Female casualties requiring immediate use of type O blood should receive Rh-negative, if available. This will preclude future problems associated with sensitization.

Transfusions may be associated with complications, including transfusion reactions, transmission of disease (donor pool dependent), and coagulopathy (in patients receiving massive transfusions) secondary to either dilution or a disseminated intravascular coagulation (DIC)-like state.⁷⁸ Transfusion related

⁷² Ibid.

⁷³ NATO Handbook of Emergency War Surgery.

⁷⁴ Bellamy, Causes of Death.

⁷⁵ Ibid.

⁷⁶ Ibid.

⁷⁷ NATO Handbook of Emergency War Surgery.

⁷⁸ U. S. Department of Health and Human Services, Centers for Disease Control and Prevention. HHS Publication No. (CDC) 94-8280. June, 1994. pg. 157.

transmission of an immunosuppressing virus is but one of many transfusion-related infectious complications.⁷⁹

Transfusion of massive quantities of blood may result in hypothermia. Caregivers can alleviate potential hypothermia by using a blood-warming apparatus (and air warming if the administering artificial respiration.) Additional preventive measures include providing the casualty a blanket, ensuring sufficient environment heat, and regularly checking the casualty's body temperature.

⁷⁹ Ibid.

CHAPTER THREE

CURRENT MEDICAL EVACUATION DOCTRINE

Army Medical Structure

To appropriately assess whether current medical evacuation is adequate for the future, it is important to start with the basics of how the medical system is structured. This chapter provides an overview of the combat health support system. The goal of combat health support is to provide a continuum of care, from the point of injury through successive echelons of care, to definitive and rehabilitative hospitals in the continental United States (CONUS) sustaining base.⁸⁰ The underlying idea is that the system is a continuum of care in which a soldier injured on the battlefield will be provided a full range of services, from simple first aid in the theater to more definitive care at a fixed facility within CONUS or Europe.⁸¹

In addition to the Army's wartime mission, the Army Medical Department (AMEDD) is also responsible for health care to its beneficiary population. To execute both the peacetime and wartime missions, AMEDD employs a creative structure of medical personnel and capability. Most of the Army's active component physicians and other healthcare professionals are assigned to military treatment facilities that treat soldiers and beneficiaries. This allows healthcare professionals to practice critical medical skills in peacetime by treating patients regularly.⁸² These same medical personnel also staff Army combat units when they are called upon for contingencies. The deployable Army medical force consists of units and personnel from both the Active Component (AC) and the Reserve Components (RC.) Roughly 70 percent of the Army's wartime capability structure being in the RC.⁸³

Linking deployable combat units and fixed treatment facilities is a unique personnel mechanism known as the Professional Filler System (PROFIS). When contingencies arise, active-component healthcare professionals move from garrison treatment facilities to their assigned units. Reserve

⁸⁰ Headquarters, Department of The Army, FM 8-10-1, *Tactics, Techniques and Procedures for the Medical Company*, Washington, DC, 29 DEC 1994 4-2.

⁸¹ Headquarters, Department of the Army; FM 8-10, *Health Service Support in a Theater of Operations*, 1 March 1991, p. 3-1.

⁸² Congressional Budget Office, *Restructuring Military Medical Care*, Washington, D.C.: CBO, July 1995.

⁸³ <http://www.globalsecurity.org/military/agency/army/usar.htm>.

component medical personnel then replace those deploying to combat. In many cases, reserve personnel deploy to participate in contingency missions. If required, the Army can contract medical care required for peacetime beneficiaries.

Resourcing and capabilities of the healthcare system have received considerable attention in recent years. After Desert Shield/ Desert Storm, a General Accounting Office report questioned the capability of AMEDD to provide adequate medical care had the ground war started earlier, lasted longer, or resulted in the predicted number of casualties.⁸⁴ The report asserted that information systems used to assign personnel to medical units contained out-dated and incomplete information and that some medical personnel had not trained during peacetime to perform their wartime missions.

Deployments significantly stress both the Army's warfighting organization and its personnel system.⁸⁵ The Army routinely uses the PROFIS system, and combinations of active and reserve component units, to provide medical personnel for contingency operations. This personnel shift can disrupt routine, and may result in temporary personnel shortages, creating inefficiency within each organization involved.

The Wartime Medical Mission: Conserve the Fighting Strength

The AMEDD's wartime mission is to support the line commander by conserving the fighting strength so that he may accomplish the military mission. The AMEDD's mission then encompasses the following objectives: (1) save lives; (2) clear the battlefield of casualties; (3) provide state-of-the-art care; (4) return a soldier to duty as rapidly as possible or evacuate him back to a higher echelon of care for more definitive treatment; and (5) provide the most benefit to the maximum number of personnel.⁸⁶

The theater medical support system is designed to reduce the incidence of disease and non-battle injury (DNBI) through good preventive medicine support to the troops. In any given contingency, the

⁸⁴ General Accounting Office (GAO), *Operation Desert Storm: Full Army Medical Capability Not Achieved*, GAO/NSIAD-92-175, Washington D.C.: GAO, August 1992.

⁸⁵ Congressional Budget Office (CBO), *Making Peace While Staying Ready for War: The Challenges of U.S. Military Participation in Peace Operations*, Washington, D.C.: CBO, December 1999.

⁸⁶ *Operational Branch Concept Combat Health Support*, Directorate of Combat and Doctrine Support, U.S. Army Medical Department Center and School, Fort Sam Houston, TX, 8 September 1994, p. 6.

commander will have a limited set of resources with which to save lives, treat and return a soldier to duty as far forward as possible, or stabilize and evacuate a soldier to a more definitive level of care.

The combat health support system implemented at the tactical level is designed to acquire, triage, and provide medical care for personnel operating in combat. The Army-wide system depends upon a modular concept derived by recognizing those common medical functions performed at the tactical level.⁸⁷

Tactical combat health support units represent packaged capability to accomplish those common medical tasks. These “modules” are focused on casualty assessment, collection, evacuation, treatment, and initial surgical intervention. This concept of modularity allows tailoring the medical support necessary for the contingency at hand. Modularity also affords flexibility within the contingency package.

Echelons of Care

To meet wartime needs, health service support in the theater of operations is organized into echelons of care. These echelons extend rearward throughout the theater and depend on a reliable evacuation system.⁸⁸ The health care at each successive echelon includes the capabilities described respectively below, as well as the previous level of care. Casualties are evacuated through the system until they reach a facility capable of beginning decisive intervention, with sufficient time to perform necessary procedures and the bed capacity to retain the patient. Triage is accomplished at each echelon of medical care.

Echelon I--the first medical care a soldier receives--is unit-level health care that includes treatment and evacuation from the point of injury or illness to the unit's aid station. This echelon includes immediate lifesaving measures, DNBI prevention, combat stress support, casualty collection, and evacuation to supporting medical treatment. At this echelon, medical care encompasses self-aid, buddy aid, combat lifesaver, combat medics, and a treatment squad (battalion aid station).

Echelon II care is provided by medical companies, support battalions, medical battalions, and forward surgical teams, and includes intra-theater patient evacuation assets. This echelon will treat and hold soldiers who can be returned to duty within 24 to 72 hours. Echelon II provides initial resuscitative care

⁸⁷Headquarters, Department of the Army, FM 8-10-5, Washington, DC, 10 June 1991. 1-3.

that saves life or limb and stabilizes patients for evacuation to Echelon III or beyond. Blood and blood products may be found at Echelon II if refrigeration assets are available.⁸⁹ Organic medical units may be augmented with other medical specialties. Of extreme importance is consideration to augment Echelon II with emergency surgical procedures for life or limb saving resuscitation.

The surgical medical detachment is a corps asset that may deploy forward as necessary to support division or task force operations.⁹⁰ It is organized to provide early resuscitative surgery for seriously wounded or injured casualties, to save lives, and to preserve physical function. Early surgery is considered if a likely delay in the evacuation of a patient threatens life or the quality of recovery. This detachment is resource intensive and must collocate with a patient holding squad for support. Normally, it will attach to a treatment platoon and collocate with a division clearing station. The detachment can, however, be employed in the brigade support area during independent brigade combat team operations.

Echelon III provides a higher level of surgical and medical resuscitative capability. In addition to general surgeons and orthopedists, other surgical specialists will be present. The scope of treatment requires clinical capabilities normally found only in a hospital properly staffed, equipped, and located in an environment with a low level of threat from enemy action. This level of care constitutes the definitive treatment that is needed to return many patients to full duty.

Echelon III is corps-level health service support, which includes evacuating patients from supported divisional and non-divisional units and providing resuscitative and hospital care. In addition, Echelon III includes providing area health service support within the corps' area to units without organic medical units. Echelon III care is provided by units found beyond the division structure, such as combat support hospitals or evacuation hospitals.⁹¹ Patients unable to survive movement over long distances receive

⁸⁸ Operational Branch Concept; Combat Health Support, Director of Combat and Doctrine Support; US Army Medical Center and School; Ft. Sam Houston, TX, 8Sept 1994, p6

⁸⁹ Normally at this level, only liquid blood, type O is available.

⁹⁰ US Department of the Army, FM 8-10-6, Medical Evacuation in a Theater of Operations, Headquarters, Department of the Army, Washington DC, 31 October, 1991, FM 8-10-5.

⁹¹ FM 8-10-1.

surgical care in an Echelon III hospital. In these theater hospitals, patients receive care that will either allow them to be returned to duty or stabilized for evacuation out of the corps or out of the theater altogether.

Echelon IV is communications zone-level health service support, which includes the receipt of patients evacuated from the corps. In addition to the surgical capability provided in Echelon III, Echelon IV provides further definitive therapy for recovering patients who may then return to duty within the theater evacuation policy. Here, patients receive further treatment to stabilize them for their evacuation to CONUS. This level of care is adapted to the precise condition of the patient; it is normally provided by a fully staffed hospital delivering the care necessary to complete the patient's recovery.

Echelon V is the most definitive care provided to all categories of patients. Echelon V provides individualized convalescent, restorative and rehabilitative treatment in CONUS and OCONUS Army hospitals.

Within these different echelons of care, health service support in the theater of operations is made up of a number of different elements, including hospitalization, command elements, laboratory services, medical logistics and blood management assets, evacuation assets, combat stress support, preventive medicine support, dental services, and veterinary services. All of these are components of Echelons I through V, and are integrated to form the theater medical system.

Treatment and Evacuation of Patients

Employing the medical system on the battlefield is a complicated process. As with all battlefield operating systems, the medical system implementation must adjust for specific mission, enemy, terrain, time available, and civilian implications. Modules and expertise can be task organized or tailored as needed, but generally aligns with parent units as described below.

Self/Buddy Aid: Immediate far-forward first aide is essential in the battlefield. Medical personnel may not be the first person to reach a soldier to apply life saving emergency medical treatment. All

soldiers in the Army, therefore, learn basic first aid skills during their basic and initial entry training. As soon as is tactically feasible, a wounded soldier or his buddy may begin to assess and treat his wounds.

Combat Lifesavers (CLS): The bridge of medical skills between basic first aid and formally trained medics comes in the form of a Combat Lifesaver. Combat Lifesavers are non-medical unit members who have received additional training to increase their skills beyond basic first aid procedures. The CLS is not intended to replace a shortage of medics, however, but to slow deterioration of a wounded soldier's condition until trained medical personnel arrive. His primary duty does not change. He is a fighter first and medic second. Nonetheless, the CLS program is considered a fundamental concept that has proven very effective in saving wounded soldier's lives.⁹²

CLS training is conducted at the unit level. Battalion commander selects qualified medical personnel to provide classroom instruction, and to test, certify and periodically re-certify the unit's Combat Life Savers. The CLS is able to initiate and maintain intravenous infusion, and may provide limited care to alleviate suffering for wounded soldiers. As with individual buddy aide, the CLS medical duties are performed when the situation permits. The CLS carries a compact medical equipment set and receives his medical supplies through his unit supply section, or any medical team or company carrying supplies.

Medical Platoons: A medical platoon is organic to each combat battalion HHC.⁹³ Each platoon is organized with a headquarters section, two treatment squads of two teams, an ambulance squad, and a combat medic section.⁹⁴ The platoon leader of the medical platoon is additionally designated as the "battalion surgeon."⁹⁵ A physician assistant is also assigned to provide general health care. The platoon headquarters normally collocates with the treatment squad and operates the Battalion Aid Station

⁹² US Department of the Army, FM 4-02.4, Medical Platoon Leaders' Handbook, Headquarters, Department of the Army, Washington DC, 24 August, 2001. Appendix C.

⁹³ Ibid, 2-15.

⁹⁴ Ibid, 2-17.

⁹⁵ US Department of the Army, FM 8-10-6, Medical Evacuation in a Theater of Operations, Headquarters, Department of the Army, Washington DC, 31 October, 1991, 2-2. Medical platoon leaders are medical service officers during peacetime. When a unit deploys to combat, a physician replaces the peacetime platoon leader. Unit level surgeons are usually not truly surgeons, but general practitioners. The Brigade level surgeon will more often be a physician, general practitioner, without a peacetime medical service officer acting as the platoon leader.

(BAS.)⁹⁶ The aid station medics assist the battalion surgeon with sick call and with combat casualty care. Aid station combat casualty care consists largely of resuscitative measures.

The Combat Medic: Combat medics are organic to the medical platoons or sections of combat and combat support battalions and are attached to the companies of the combat battalions.⁹⁷ The combat medic's main objective in the initial management of the casualty is to do no further harm and to evacuate the patient rapidly to a definitive treatment center. Combat medics are allocated to mechanized infantry on the basis of one medic per platoon and a senior medic for each company.⁹⁸ Normally, one ambulance team is positioned in the company area. Other ambulances provide evacuation within the battalion area of operations.⁹⁹ Ambulance teams are mobile trauma specialist teams, medics with emergency medical treatment, and trauma management training.

The platoon combat medic normally locates with, or near, the supported element leader. When the combat platoon is moving on foot in the platoon column formation, the medic positions himself near the element leader trailing the base squad forward of the second team.¹⁰⁰ This formation is the platoon's primary movement formation. When the platoon is mounted, the combat medic will normally ride in the same vehicle as the platoon sergeant. The medic will provide care to the occupants of his vehicle. He will not be able to treat occupants of other vehicles while the platoon is moving or engaged.

Company Medic: The company combat medic normally collocates with the first sergeant. When the company is engaged, the combat medic will remain with the first sergeant and provide medical advice as necessary. As the tactical situation allows, he will provide medical treatment and prepare patients for evacuation. The combat medics assigned to the company's evacuation vehicle work with the company medic in a coordinated effort.

⁹⁶ FM 4-02.4, 2-17.

⁹⁷ US Department of the Army, FM 4-02.21, Division and Brigade Surgeons Handbook, Headquarters, Department of the Army, Washington DC, 15 November, 2000. 2-21

⁹⁸ In armor units, only one medic per company is authorized.

⁹⁹ FM 4-02.4, 2-21.

The battalion surgeon is responsible for first echelon medical care. When casualties occur, first aid will usually be rendered by buddy aid or perhaps CLS care. A platoon medic or company medic must move to casualty's location or the casualty must move to the medic. The combat medic makes his assessment; administers initial medical care; initiates a DD Form 1380 (Field Medical Card); then requests evacuation or returns the individual to duty. A vehicle from the evacuation section (usually pre-positioned forward) picks-up the patient and transports him to the BAS.

When the patient arrives at the BAS, initially he is taken to a triage point. When the treatment teams are collocated, the PA usually performs triage, unless the treatment teams are separated or a mass casualty situation exists. The patient is categorized as immediate, delayed, minimal, or expectant. Depending upon his triage category and the patient load, the patient is then taken to either the patient holding area or the treatment area. Ultimately, a medic administers treatment and the casualty is evacuated to the Division Clearing Station or is returned to duty.

The ambulance section transports casualties from the battlefield to the aid station. Higher echelon ambulances, either ground or air, will move the casualty from the aid station to a higher level of care or, depending on the circumstances, may evacuate directly from the battlefield to a surgical facility. Evacuation by air provides the flexibility to evacuate casualties from the point of initial wounding directly to an area providing first-line resuscitation capability and beyond. This technique markedly reduces the time lapse from initial wounding to definitive care, and has decreased morbidity and mortality rates in recent conflicts. Division level medical companies do not have organic aeromedical assets, and require augmentation from higher echelons for this capability.

Patients are evaluated at aeromedical evacuation battlefield collecting points and categorized as to their relative needs and general stability. From these collection points, and with an awareness of each casualty's individual clinical needs and personal stability, further retrograde movements are programmed.

¹⁰⁰ FM 71-2, Tank and Mechanized Infantry Battalion Task Force, Headquarters, Department of the Army, Washington, DC, 27 September 1988, 7-35.

CHAPTER FOUR

BIOMEDICAL ADVANCEMENTS

Due to increased emphasis in the civilian community, significant strides have been taken to implement measures to reduce the occurrence and severity of injury in the United States.¹⁰¹ The national investment in injury research has increased, and the field of injury science has developed and matured, attracting the interest of investigators from a wide range of disciplines.¹⁰² Important advances have been made in delivering emergency services and treatment to injured patients, saving lives, and reducing disability.

Recent research in injury science has motivated increasing interest in immediate medical treatment for traumatic injuries, and improved processes of recovery healing. The information revolution has inspired extraordinary leaps in almost every periphery technical science. Medical research certainly has benefited.¹⁰³ Major advances in the field of molecular biology, coupled with advances in genomic technologies, have led to an explosive growth in the biological information generated by the scientific community. These advances are providing information about how cells respond to injury and how their normal functioning can be preserved.

The biotechnology industry now surpasses the aerospace industry in market capitalization, research expenditures, and complexity.¹⁰⁴ Sensory devices, and imaging systems have come together to provide patients more efficient diagnoses with convenient, yet effective treatment. Microscopic cameras and tools are allowing physicians to journey into the very deepest canals of the human body. Technologically advanced methods of computerized axial tomography (CAT,) positron emission tomography (PET,) and nuclear magnetic resonance imaging (MRI) have begun to replace invasive exploratory surgery.¹⁰⁵

Genetic engineering and improved understanding of genetic base of the immune system introduce great opportunity in the development of vaccines and enhancement of immune system responses.

¹⁰¹ National Research Council, *Reducing the Burden of Injury*, 1999.

¹⁰² Ibid.

¹⁰³ For a general discussion see *The Genetic Revolution*, Bernard D. Davis; Johns Hopkins University Press, 1991.

¹⁰⁴ Kenneth H. Keller testimony before the Committee on Health, Education, Labor, and Pensions; May 10, 2001.

¹⁰⁵ Ibid.

Significant advances in genetics and molecular chemistry have opened the doors to understanding the very essence of life itself. Understanding of the complex nature and origins of diseases permit development of drug therapies and treatment regimens only barely hoped for in the past. Similar knowledge presents understanding of injury and individual recovery. Genetic and molecular biotechnology will ensure blood type matching for transfusions, and will very likely reduce rejection rates in organ transplants.¹⁰⁶ The same technological concepts will supply sensitive tests for dangerous contaminations and tissue match. The medical and biomedical sciences will continue to enjoy rapid growth, and significant advances for several decades.

Without question, the United States leads the world in biomedical research from spending to scientific breakthroughs to the drugs, devices and processes that apply the breakthroughs to improving American health.¹⁰⁷ Many promising technologies under development or on the horizon could help to improve combat and battlefield casualty care. These include new types of protective clothing that provide greater protection against small-arms fire or shrapnel and against chemical and biological threats.

A range of new sensory technology is on the horizon, and will soon be available. Promising technologies could produce devices such as advanced biochemical sensors and personal status monitors, some of which could be implanted, that perform as personal data boxes, analogous to black boxes in aircraft. Advanced protective clothing may incorporate some of these sensors to notify medical personnel of injury or impending disease or other biological troubles. Incorporating various technologies, such clothing could automatically administer physiologically protective agents as needed, or even some forms of emergency care. Other advances that are more specific to casualty treatment and evacuation are discussed below.

¹⁰⁶ Until synthetic substitutes are developed and approved, human donors are necessary. Blood and blood products remain precious, and ensuring safety in the blood supply is a critical function. Douglas Starr's, *Blood* provides an excellent analysis of the history, progress and potential for development blood technologies.

¹⁰⁷ Lewis Group Inc. Report on Biomedical Technology Industry

The Laryngeal Mask Airway

The laryngeal mask airway (LMA) was invented and first described by Dr Archie Brain in 1983.¹⁰⁸ It was first introduced in the United Kingdom in 1988 and in the United States in 1992 as an alternative to the traditional facemask.¹⁰⁹ The LMA consists of a flexible curved silicone tube with a universal polypropylene connector on one end, and an elliptical mask made from a silicone polymer at the other end. The system incorporates an inflatable cuff around the mask margin.¹¹⁰

The LMA is inserted via the mouth until its distal end lies in the hypopharynx and covers the glottic opening, at the crossroads of the digestive and respiratory tracts.¹¹¹ The cuff is then inflated against the posterior perimeter of the larynx, producing a seal that remains airtight at moderate airway pressures.

The LMA is being used increasingly as a first line device for securing the airway of unconscious patients both in hospital and pre-hospital settings. The LMA provides a useful adjuvant to airway management.¹¹² Studies show that it is easy to place, and it has been used in emergency circumstances in the difficult airway after failed intubations. The LMA does not, however, prevent the stomach from becoming inflated with air or prevent against aspiration of regurgitated stomach contents.¹¹³ Nonetheless, it can provide life-saving assistance in emergency management of the airway.

Attenuated External Defibrillators (AED)

Defibrillators are life saving devices used when the heart is beating irregularly and ineffectively (fibrillating.) Tachycardia and fibrillation often stem from extreme blood loss as a result of traumatic

¹⁰⁸ J. Pennant and Philip White, *The Laryngeal Mask Airway. Its uses in Anesthesiology*. Anesthesiology Vol. 79, No. 1. Jul 1993.

¹⁰⁹ Mark Pinoski, *The Laryngeal Mask Airway: Uses in Anesthesiology*. Southern Journal of Medicine, June 1996.

¹¹⁰ Ibid.

¹¹¹ J. Pennant and Philip White, *The Laryngeal Mask Airway. Its uses in Anesthesiology*. Anesthesiology Vol. 79, No. 1. Jul 1993.

¹¹² The American Heart Association recommended laryngeal mask airways as an alternative emergency airway for both Advanced Cardiovascular Life Support (ACLS) and Basic Life Support (BLS) in its *Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiac Care* issued in August 2000. http://www.lmana.com/prod/components/press_releases.html.

¹¹³ Mark Pinoski, *The Laryngeal Mask Airway: Uses in Anesthesiology*. Southern Journal of Medicine, June 1996.

injury. The AED administers an external electric shock through the chest wall to the heart via conductive adhesive pads in an effort to restore normal heart rhythm.¹¹⁴

Defibrillators may become more readily available as a result of FDA's approval in 1996 of a smaller portable version that may be particularly beneficial on the battlefield. As electronic devices and computerization advance, defibrillators could become smaller, and easier to use. Reliable, ruggedized compact models could equip combat medics and their vehicles.

Tissue Engineering

Tissue engineering is another multidisciplinary endeavor to advance health through medical care. Applying the principles of biology and engineering, this effort is focused on developing or manipulating laboratory-grown cells, tissues or organs to replace or support the function of defective or injured body parts.¹¹⁵ It is different from bioengineering in that it involves living tissue, where as bioengineering involves the use of manmade materials, such as plastics and metals, within living systems. Unlike prostheses made of manmade materials, engineered tissue becomes an integrated part of the patient.¹¹⁶

Tissue engineering generally includes three basic approaches to grow new tissue. One approach is to design and grow human tissues outside the body for later implantation to repair or replace diseased tissues.¹¹⁷ The most common example of this form of therapy is the skin graft, which is used for treatment of burns. Skin graft replacements have been grown and used clinically for more than 10 years. Donor, or synthetic mechanical organs may soon be protected from rejection in the recipient by using similar sheath-like material to package them. This concept is opening up enormous new possibilities for providing artificial organs to replace the pancreas or the liver, where natural organs for transplantation are in very limited supply.¹¹⁸

A second approach is to implant devices that induce the regeneration of functional human tissues. This approach relies on the purification and large-scale production of appropriate "signal" molecules, like

¹¹⁴ FDA talk paper, <http://www.fda.gov/bbs/topics/ANSWERS/2001/ANS01082.html>.

¹¹⁵ Robert Langer, Joseph P. Vacanti. *Tissue engineering*. Science. 1993;Volume 260; p920.

¹¹⁶ Ibid.

¹¹⁷ Nerem, RM. *Cellular engineering*. Annals of Biomedical Engineering. 199; Volume19; p529 –545.

growth factors, to assist in biomaterial-guided tissue regeneration. A recent breakthrough development in three-dimensional polymer configuration will propel extraordinary structural leaps in tissue reconstitution.¹¹⁹ An example is the biomaterial matrix used to promote bone re-growth for periodontal disease.

The third approach is development of devices containing human tissues designed to replace the function of diseased internal tissues. To do this, scientists must isolate cells from the body, incorporate other tissue growth techniques, such as stem cell therapy, place them on or within structural matrices, and finally implant the new system back into the body or using the system outside the body. Muscle, tendon, cartilage, and bone repair, are all examples of this method.

Although scientists have grown cells outside the body for many years, the possibility of growing complex, three-dimensional tissues is relatively new. This sophisticated process requires input from many types of scientists, including the problem solving expertise of engineers, hence the name tissue engineering. Perhaps the most perplexing obstacle in moving three-dimensional tissue growth into organ development is the requirement to feed the tissue with blood.¹²⁰ Although a patient's own blood vessels can penetrate and sustain a skin graft, they can't grow fast enough to keep a mass of liver cells alive. "You get cell death before the vessels arrive," says pediatric surgeon and tissue engineer Joseph Vacanti of Massachusetts General Hospital.¹²¹ Vacanti and his research team of are currently working on a blood supply circuit to overcome this obstacle.

Advanced Hemostatic (blood control) Agents

These technologies assist in the first step of circulatory resuscitation—stop the bleeding. Implementing such a capability early on provides for effectiveness in all other life saving activities.

¹¹⁸ Keller, Testimony before the committee on Health, Education, Labor and Pensions.

¹¹⁹ Ibid.

¹²⁰ Robert Langer, Joseph P. Vacanti. *Tissue engineering*. Science. 1993;Volume 260; p 924-926.

¹²¹ Fairley, Peter, *Blood from a Chip: Bioengineers grow a circulatory system on silicon*. Technology Review Magazine, Volume 1, Issue 2. May 2000.

Although a number of companies are developing various products potential use products can be categorized into treatment concepts: external, internal, or intravascular agents.

External agents include sprays, gels and bandages applied directly to wounds on the battlefield that coagulate and protect large areas of abrasion or avulsion (detachment of a body part). These agents could be used to quickly stop vascular and arterial bleeding which occurs in various forms of trauma. One such product, CoStasis,¹²² is a sprayable liquid that hastens the body's clotting mechanism. The active ingredients, both derived from cows, are connective tissue (collagen) and a clot-promoting material (thrombin). When sprayed onto bleeding tissue, the product forms a gel that adheres to the tissue, retards the bleeding, and produces a physical barrier to blood flow. It functions without manual pressure, and is designed to remain intact during the critical wound-healing period. The body absorbs the material over time. CoStasis does not use components of human blood, so contamination risk is eliminated.¹²³

The hemostatic patch is a thin, sheet-like pad with a mixture of clot-promoting epsilon aminocaproic acid and thrombin on one side which, when pressed against the lesion for three to five minutes, will stanch the flow of blood. Components listed here are currently FDA approved. One device the Hemarrest patch by Clarion Pharmaceuticals, is undergoing human testing.¹²⁴ Similarly, the Army began trials with a Red Cross dressing impregnated with blood components, fibrin and thrombin, in 2001. If trials are successful, the dressing may be available in 2006.¹²⁵

Hemostatic adhesives are surgical adhesives with hemostatic and sealing properties. Current products are usually made of biological tissue glue comprised of fibrinogen, thrombin, and aprotinin. These adhesives replicate the natural blood-clotting process in surgical procedures or wound closure.

Internal agents consist of hemostatic foams or fluids that can be injected into body cavities to stop bleeding from penetrating trauma. This type of product could be especially beneficial for internal injuries. Hemadex (Trademark) represents a novel hemostatic technology using micro porous polymer

¹²² FDA approval list of new devices, <http://www.fda.gov/cdrh/mda/docs/p990030.html>.

¹²³ Ibid.

¹²⁴ Clarion Pharmaceuticals, Inc. Sources: Patent information - 07/08/97; PR Newswire - 10/26/98.

¹²⁵ Medical Research and Materiel Command, Newsletter September 20, 2001.

particles for effecting almost instantaneous hemostasis at wound sites, even in the presence of profuse bleeding. The technology consists of an engineered biopolymer, microporous particle designed to act as a sieve to dehydrate the blood, concentrating proteins and platelets in order to accelerating the natural clotting cascade.¹²⁶

Intravascular agents exploit hemostatic accelerant technology developed by three University of California researchers. Novel cross-linked polymer compositions of antifibrinolytic pharmaceuticals antihemorrhagic accelerate blood component clotting via multiple pathways. These agents would be introduced into the bloodstream to affect blood clot formation and breakdown.

Further research in the related sciences of this area will certainly advance similar products and techniques to employ them. Combinations of the products discussed above could be used on the battlefield as needed to stop massive blood loss in casualties suffering from multiple wounds.

Blood Substitutes and Oxygen Capacity Enhancers

The effort to develop a substitute for blood is almost as old as medicine. Historians have recorded experiments that included using milk, urine, ale, and animal blood. The modern drive to develop a blood substitute got off to a low-key start in the 1950s, but became urgent in the 1980s when the nations blood supply fell vulnerable to the AIDS virus, and blood donation rates dwindled.¹²⁷ As a result the Red Cross, the Food and Drug Administration, National Institute of Health, and even the Department of Defense held a series of conferences that brought researchers and health policy planners together for the first time to confront the problem.¹²⁸

This long-sought-after goal of a substitute for blood may soon be reached. Clinical trials are underway for a number of products aimed at providing the primary function of blood, tissue oxygenation. Moreover, artificial blood products hold promise of several characteristics that may allow for a much wider range of uses than simply transfusing donated blood in reaction to trauma, shock or during surgery.

¹²⁶ Medafor, Inc. Press Release, FDA Approves Medafor's Unique Hemostatic Technology. 2001.

¹²⁷ Douglas Starr, *Blood, an Epic History of Medicine and Commerce*. Alfred A. Knopf, Inc, New York, 1998.

¹²⁸ *Ibid*, 268-290.

They include oxygenation of ischemic tissue during myocardial infarction or stroke, enhancing the effect of radiation therapy of cancerous tumors, and as a drug delivery medium through the pulmonary circulation.

Blood performs numerous functions, but research has centered primarily on finding a way to replace its role in tissue oxygenation. There are basically two approaches being pursued. One uses perfluorocarbons (PFCs) as an oxygen-carrying vehicle, and the other concentrates on using hemoglobin. PFCs have a gas-carrying capacity that greatly exceeds that of hemoglobin.¹²⁹ They can also transfer gases (oxygen for carbon dioxide, just as hemoglobin does) more quickly than can hemoglobin, since they do not have to diffuse across the membrane of a red blood cell. Because PFCs are inert and do not dissolve in plasma, they must be emulsified with another agent to form particles that disperse in the blood. These particles usually clear from the circulation in four to 12 hours after injection.

Most of the research in blood substitution products centers on the manipulation of the hemoglobin molecule.¹³⁰ Researchers use human hemoglobin (usually harvested from out-of-date donated blood), animal blood (most often from cows), and hemoglobin manufactured by genetically altered microbes. All have drawbacks. The use of outdated donor blood confronts the same problem of insufficient supply faced by blood banks.

Hemoglobin-based oxygen carriers (HBOCs) are a new class of oxygen therapeutics that may be useful in situations of acute anemia, ultimately including the maintenance of isolated tissues and in the reperfusion of transplanted organs. When oxygen is reintroduced to ischemic tissue by a range of fluids, including blood, this can lead to local and systemic tissue injury as a result of the formation of reactive oxygen species. Hemoglobin-based oxygen-carrying systems have several advantages. Unlike the red blood cell, they are free of antigens and are therefore universally compatible.¹³¹ So far, at least four hemoglobin blood substitutes have entered into clinical trials.

¹²⁹ Douglas Starr, *Blood, and Epic History of Medicine and Commerce*. See also BloodBook.com: *Information for Life*, July 16, 2001. <http://www.bloodbook.com/>.

¹³⁰ Douglas Star, *Blood*, 1988, 352-354.

¹³¹ BloodBook.com: *Information for Life*, July 16, 2001. <http://www.bloodbook.com/>: "Sustitutes."

The concept behind oxygen capacity enhancers includes methods to reduce metabolic oxygen requirements and methods to increase oxygen delivery to partially answers the body's demand for oxygen to tissues after injury. Oxygen capacity enhancers could be used for resuscitative measures, prevention of shock or follow-on treatment for tissue damage.

Just as synthetic blood substitutes and low volume, high density resuscitation fluids and oxygen carrying capacity enhancements could inhibit shock and secondary trauma damage, white blood cells and plasma, or their substitutes may soon be developed and could be injected on the battlefield. White blood cell substitutes could help the body fight against a chemical or biological attack as well as to assist wound healing.

Transfusion

Autotransfusion devices may be available in future wars. There are basically two types of such devices. Both add small amounts of anticoagulant to the collected blood. One simply collects the blood, filters it and reinfuses it. The other type collects the shed blood, washes and centrifugally separates out the red blood cells, and then reinfuses them. These devices may be practical in the resuscitation area for casualties with substantial and ongoing hemothorax. In the operating room, these devices may be applicable in extremity wounds or in cases of uncontaminated hemoperitoneum.

Non-invasive Ultrasound (or other imaging device)

Rapid and inexpensive computing capabilities, in conjunction with signal and image processing, have accelerated change significant advances in non-invasive surgery.¹³² Medical imaging is still undergoing a very rapid change toward higher sensitivity and specificity, improved resolution and image quality, smaller equipment, cellular and molecular-level imaging, higher dimensions and real-time imaging, as well as new imaging modalities, e.g., optical coherence tomography and electrical impedance imaging.

¹³² Peter Kaczowski, *Development of a High-Intensity Focused Ultrasound System for Image-guided Ultrasound Surgery*. Paper presented to Acoustical Society of America, Ft Lauderdale, FL; 3 DEC 2001.

During the last three decades of the 20th century, medical imaging, which for nearly 70 years had almost exclusively depended on conventional film/screen X-ray imaging, has experienced revolutionary technological growth resulting in the development and commercialization of a plethora of new imaging technologies.¹³³ X-ray Computed Tomography, Magnetic Resonance Imaging (MRI,) ultrasound, and various imaging techniques based on nuclear emission have all expanded the arsenal of imaging tools that will enhance detection and diagnosis in disease or injury.¹³⁴

New methods in ultrasound and MRI provide higher resolution information in two and three spatial dimension, with acquisition and display occurring nearly in real time.¹³⁵ Recent research has shown that High Intensity Focused Ultrasound (HIFU), or Focused Ultrasound (FUS), can be used to rapidly kill tissue (directly applicable to cancer treatment, for example) and to stop internal bleeding by cauterizing injured organs or blood vessels. The great promise of ultrasound therapy is completely non-invasive surgery, possibly even performed without the need for anesthetic. Most of the body's innervation is in the skin, and many surgical ultrasound procedures might be completely painless.¹³⁶

Non-invasive ultrasound methods could allow in depth casualty diagnosis resulting in more accurate assessment and appropriate treatment for the casualty. This capability, in conjunction with others mentioned above, could assist a medic to quickly locate a bleeding artery and patch it. Most importantly, such a capability could identify internal bleeding that is very often not apparent in the first few minutes after injury.

¹³³ Ibid.

¹³⁴ Keller.

¹³⁵ Peter Kaczowski.

¹³⁶ Ibid.

CHAPTER FIVE

CONCLUSION

A New Concept of Casualty Care

Is the Army's medical evacuation system adequate to support Army forces in the contemporary operating environment? Not entirely. Current doctrine is to some extent the product of military and medical evolution thus far. Over the centuries, armies have learned and adapted continuously in an effort to advance the art and science of warfighting. As civilizations and warfighting have advanced, so has the art and science of caring for wounded soldiers on the battlefield. Today's medical doctrine naturally grew from scientific advancements in medicine as well as lessons learned in historical warfighting. Today's doctrine is based sensibly upon a flexible system of modular medical organizations. Employment philosophy is responsive medical care and far forward treatment to reduce disease and non-battle injury, and care for and evacuate battle casualties. These foundational tenets of medical support are commendable and should be continued.

However, change and adaptation of systems in the light of progress continue. The dynamics of a rapidly changing world suggest reassessment of current Army forces. Implications of the new operating environment dictate carving out incomparably modernized, overwhelmingly effective Army forces to meet potential challenges. This force evolution will be inherently difficult, as the process must address requirements for strategic force projection as well as quick and decisive tactical operations.

Consequently, reassessment is indicated of all supporting systems within the Army. Although the American military medical care stands superior in the world, the current medical doctrine must continue to evolve with the supported force to maintain that superiority. To care for soldiers in combat, America has traditionally configured complex, redundant medical capabilities within resilient theater and global infrastructures.

As with other logistics functions, there was a system of progressively more capable facilities, stretching from combat units rearward to the continental United States. Medical focus was on returning patients to duty from the lowest possible echelon of care. Patients who could not be returned to duty

within prescribed times were evacuated to the next higher echelon. Patients often spent several weeks in the theater health care system before being evacuated to hospitals outside the theater. Over that time, patients stabilized and required little care en route.

Army forces will now become more deployable and extremely agile to accommodate rapidly changing strategic environments and operational requirements. Soldiers will deploy to hostile areas of conflict with little or no infrastructure. Tactical and operational situations may not afford build up of extensive support assets. Small units will likely operate independently, in remote areas. One primary objective of the Army vision is to deploy powerful land forces more rapidly in order to achieve quick conflict termination. Future combat forces may be expected to execute full-scale combat operations immediately upon arrival in theater. Consequently, early entry force packages are likely to be structured to maximize combat power, simultaneously minimizing logistical “footprint” in theater.

In addition to forced entry scenarios, anti-access strategies employed by potential adversaries of the future could inflict casualties prior to establishment of a theater support infrastructure. The risk of death or long-term debilitation for these early entry soldiers is further magnified in the absence of appropriate medical care, evacuation assets or definitive care facilities.

In view of these risks, medical considerations must be incorporated fully into crafting the future forces. The concept of casualty care supporting future Army forces may be dramatically different from the traditional approach. Characteristics of the future combat health support system should enhance overall capabilities of the future Army. To adequately support rapid deployment and a force projection Army, the system must be responsive, continuous, and flexible.

As described in Chapter 1, responsiveness is the extent to which the system provides the right support in the right place at the right time. While the Army has always attempted to preserve soldiers’ lives on the battlefield, the current effort is falling behind since there are modern technologies available that have not been pursued, or incorporated. This is unacceptable as it places soldiers lives at risk needlessly.

Continuity is providing uninterrupted, effective medical support to all soldiers. The current system will not suffice with respect to this criterion in the future. The non-linear and discontinuous battlefield of

the contemporary operating environment stipulates discontinuous lines of communications, and therefore discontinuous medical support, since the traditional robust and redundant theater medical infrastructure will not usually be employed, and evacuation distances are stretched. Modest casualty rates in small, dispersed units may result in a relatively large redirection of effort to treatment and evacuation at the expense of maneuver and fire-power. Clearing the battlefield and treating casualties can often be related to morale, unit cohesion, and combat effectiveness. For instance, more effort will be required of combat forces to evacuate their own casualties, and a perception that medical treatment is unavailable can reduce the willingness to fight. Therefore, if medical capability is reduced, it is likely that combat effectiveness will decline.

The system is inherently flexible, with its concepts of modularity, phased medical care and echeloned support. By improving the other criteria characteristics, the system can continue to enjoy the benefits of flexibility. The following suggestions are made to improve the medical evacuation system.

When combat care is required, the need is immediate and occurs under the most stressful of conditions. Emergency life-saving intervention must be the focus of an effective casualty evacuation doctrine. Fundamental skills consist of the ability to create a surgical airway in the casualty with a severe facial wound, the insertion of an intercostal tube in the casualty with a hemo- or pneumothorax, the occlusion of a sucking chest wound, the ability to stop bleeding from major extremity arteries, and the infusion of therapeutic volumes of resuscitation fluids for casualties experiencing shock.

The Army must place emphasis on point of injury medical care. Robust life saving capability must remain the goal for medical care on the battlefield. Early trauma intervention to stabilize casualties will allow rapid tactical evacuation to a casualty receiving and staging area for operational lift or strategic movement to more definitive care. Implementing the concept requires a carefully structured balance among immediate care and evacuation capabilities. If evacuation times are long, immediate capabilities must be sufficient to stabilize the patient before movement. The long distances implicit in the future combat operations mean that tactical aeromedical evacuation from the battlefield to definitive medical care could take several hours, and as discussed in chapter two, soldiers do not have hours to wait for care.

If great numbers of extensive facilities cannot be had, the Army must make up the life saving potential by pushing skills and resources further downward. Thus, the keys to casualty survival will be effective first aid and lifesaving emergency surgery on the battlefield.¹³⁷ Moreover, the multifaceted nature of the processes leading to irreversibility in severe shock makes it clear that therapeutic measures that occur late in shock will not likely bear any significant impact on the loss or salvage of a combat casualty's life. It is far more likely that early interventions that prevent the extensive tissue injury have potential to affect the outcome of such an incident.

Hemorrhaging and inability to breathe require immediate attention at the site of injury. Other soldiers or unit medics offer the first opportunity to perform appropriate lifesaving procedures. Better training and medical equipment are needed to provide those first responders with the skills and tools they need to be effective. Injuries to the extremities are the most common wartime wounds. A study of Vietnam War casualties found that management of such wounds and associated bleeding was inadequate. Combat medics were not trained to handle life-threatening injuries, and they lacked such simple field equipment as effective tourniquets.¹³⁸ Of course today's medics carry better equipped kits, and have benefited from these lessons.

Continual assessment is needed, however, to keep medics and non-medical soldiers up to date in training and to provide the best available equipment for their use. For example, hemostatic dressings are available now on the market, and can assist in controlling severe hemorrhaging. These dressings are a very simple form of complex technology that should be incorporated at all levels of combat health care to improve life saving on the battlefield of the future.

Most thoracic injuries do not require immediate surgery, but do require temporary closure of wounds and the ability to expand the lung and control hemorrhaging in the chest cavity. Current field dressings

¹³⁷ Ronald Bellamy, *The Causes of Death in Conventional Warfare*, 1984. Experience from the Vietnam War underscores the value of early trauma care. In that war, 78 percent of those killed in action died within 5 minutes, 16 percent in 5 to 30 minutes, and 6 percent in 1/2 to 2 hours. Eight to 10 percent of combat casualties required lifesaving surgery. Bellamy believes that better training and equipment for medics would have made a significant difference in the numbers of lives saved.

¹³⁸ *Ibid.*

do not provide adequate sealing of the chest cavity, and no device exists for field use in re-expansion of the lung and drainage of hemorrhaged blood.

Pain management is another important concern at the lowest echelons of care. Untrained personnel cannot administer current painkillers, and the drugs available usually leave patients with impaired cognitive functions. When evacuation is delayed or circumstances make it necessary to keep a casualty functional, for example, to perform self-care or unit duties, or to assist with casualty management, soldiers will need appropriate pain relievers, suited to individual needs. As sciences progress in understanding genetics, and bio-cellular functioning, the Army must demand consequential progress in pain management medications.

Forward Surgical Units

Some minimal surgical capability will be needed to support the Army's future combat units. The mission will be to perform selected emergency surgery to save life or limb, and to stabilize casualties prior to evacuation to theater or CONUS based hospital care. The medical skills required to provide this type of emergency medical care, though based upon the same fundamental medical sciences, will not be gleaned from initial civilian medical training or medical schools. This capability will require highly trained and effective surgical teams supported with state of the art surgical equipment.

The combat surgical teams of tomorrow will require comprehensive and specific skills for the tasks they will handle. The significance of their work and the stress that work inflicts will require emphasis upon cohesion and teamwork. Impromptu tasking of disparate capabilities to form ad hoc surgical units will not suffice. The Army must develop and employ these specialized teams much the same way as special operations teams are developed and employed now.

Moreover, the teams must train regularly with the equipment they are assigned and in replicated combat settings. The facility from which they will work must be compact and lightweight. It will necessarily be easily containerized, deployable, and transportable by any mode. Organization and manning of the surgical teams should be designed with modularity at the forefront. Employment will be

specific to the nature of any given conflict, and tailored to meet mission requirements. Standing organization must include, however, at least two teams made up of a surgeon, an anesthetist, and attending nurses and medics, all trained in emergency combat surgery and care. Two teams in the organization will provide 24-hour operations capability. Combinations of multiple teams then, can deploy as needed, depending on expected work load.

Depending on the nature and duration of any given conflict in which the surgical teams are employed, assigned personnel may be intensively vulnerable to acute or chronic combat stress, even occupational burnout.¹³⁹ The Army must therefore consider employment concepts that include rotating cohort surgical teams from CONUS, or areas of lighter combat intensities.

Aeromedical Evacuation

Timely evacuation from the battlefield to a hospital or hospital ship is a critical element of the Army's casualty care concept. Evacuations are often conducted as needed using aircraft of opportunity. On the dispersed, non-contiguous future battlefield, "aircraft of opportunity" may become obsolete. The Army must consider dedicated aircraft at lower levels of medical care to facilitate casualty movement.

To increase casualty survivability during prolonged evacuation flights, medical personnel must develop en route care capability. En route care will require medical technicians armed with appropriate tools, such as equipment for monitoring a patient's vital signs and physiological status, drugs and pharmaceuticals for pain and infection, and life-sustaining emergency equipment. In essence, a mobile resuscitative team should travel with casualties. The Army should consider substituting such resuscitative teams with applicable mechanical or robotic capability, to provide basic monitoring and simple treatments, such as adjusting resuscitative fluid mixes, or ventilation gasses.

¹³⁹ For general information concerning combat stress and burnout, see *The Textbook of Military Medicine, Part I, Warfare Weaponry and the Casualty: Section III: Military Psychiatry*, Office of The Surgeon General, Department of the Army, 1994.

Medical Management and Integration

The concept of minimum essential care and rapid evacuation, and the wide dispersion of medical capabilities, call for a centrally planned and well-integrated medical management system. Short-term allocation and reallocation of medical assets, management of patient flows, and management of medical workload will be essential to keeping the system balanced and responsive to combat developments. It is essential to fully integrate medical considerations into the planning and execution of all aspects of the tactical operation, including aviation support. Therefore, medical units require equal priority for information management, and communications and control assets.

Medical Training

Realistic and stimulating medical readiness training is an ongoing challenge for the military healthcare system. Medical readiness training is important to the military, as battlefield injuries are not typically seen in fixed medical facilities. The objective of medical readiness training must be to replicate the medical scenarios that could be experienced in a deployed environment.

Medical personnel must be trained to make decisions in the military medical care environment and must maintain real-time data and information systems necessary to making such decisions. Realistic scenarios and virtual simulation must be developed to provide the combat environment characteristics. Lifelike casualty training aides must be incorporated for hands-on medic training repetition, and to assess treatment processes for combat trauma injuries.

To increase the number of trauma management personnel available on the battlefield, non-medical soldiers must be trained in life saving measures beyond the first aide currently trained. All soldiers should learn to manage airway obstructions, stabilize breathing, and circulation, and to monitor vital signs. The Advanced Trauma Life Support (ATLS) course of the American College of Surgeons provides a good starting point for training both medical and non-medical personnel the skills applicable to evaluation and resuscitation. Advanced Trauma Management is a system of managing traumatically injured patients. It is an initial emergency treatment phase where personnel apply medical skills and

judgment of a higher degree in the immediate and effective management of the acutely injured or wounded (trauma) patient.¹⁴⁰

Emergency Medical Training (EMT) provides additional skills for individuals to allow rapid and accurate assessment of a casualty's condition, and resuscitative stabilization. Treatment procedures include the use of intravenous fluids and antibiotics and the preservation of the patient's airway by mechanical or surgical insertion of a breathing tube (intubation). They also include control of bleeding and the application of more secure splints and bandages.

Several of the medical advances described in chapter four will further innovate medical techniques and procedures. It is likely that scholars will better understand the sciences influencing these technologies; mass production will drive the costs lower; and equipment will become more simplified, and user friendly. Consequently, care capabilities and responsibilities can shift among medical caregivers. It is critical that the Army invest heavily to influence research, and stay abreast of current advancements.

A perfect example of shifting responsibilities is the Army's new program to combine medic and nurse skills into a single military occupational specialty (MOS.) This initiative is a step in the appropriate direction to increase medical skills at the lowest echelons of care. The Army must emphasize life saving skills outside the medical MOS's, however, to partially relieve the burden currently placed on medical personnel. To meet the challenges of the future battlefield, all soldiers should be capable of conducting those activities of today's combat lifesaver, and future combat lifesavers should receive the advanced training skills described above.

Medical Research and Development

Training alone is not enough either. To realize the full benefit of expanded knowledge and improved capabilities, medical and non-medical soldiers will require appropriate tools. As medical devices and tools become available, the Army must ensure soldiers have ready access to those resources. Some of the

¹⁴⁰ Emergency Medical Care. 1978. It should be noted that ATLS was developed by civilian physicians for use by civilians in dealing with typically civilian trauma. It has not been tested in war and may not be entirely appropriate for combat casualty care.

technologies discussed in the previous chapter may quickly manifest themselves in medical devices suitable for both civilian and military use. This will happen as a result of commonalities in civilian and military medical care.

The Army and other military services will continue to have some unique requirements, however. The Army must attempt to influence private industry to drive developments to meet those needs, which would not otherwise have occurred. To accomplish this, the Army should consider special contracting and products buys, and possibly entice private industry with mutually beneficial advertising.

Transformation will not be accomplished overnight, and the Army must find ways to improve its warfighting efforts by integrating both old and new systems as well as old and new medical care. As the Defense Science Board also points out, the United States can have a Revolution in Military Affairs using both new and legacy systems.¹⁴¹

In the very near future, basic scientific research, as well as broad medical research and development will be extremely important. Military R&D is often conducted quite effectively “in an environment of uncertainty about enemy capabilities, the costs of new technologies, and the benefits of new technologies.”¹⁴² Just as technologies developed in the 1970s and 1980s enable the combat forces today, today’s research will enable operational systems of 2020.¹⁴³

The Army should follow the high-technology industry by demanding medical research and development on a requirements basis, targeted to specific needs of the combat casualty care provider for product functionality, reliability and cost-effectiveness, in conjunction with corresponding operator training, and equipment support. The following are a few examples of the type of equipment that is needed for soldiers and medics to provide better treatment more rapidly:

¹⁴¹ The board cited *blitzkrieg* as an example of such a hybrid revolution. See *Report of the Defense Science Board*, 22.

¹⁴² Rosen, *Winning*, 52 (quote), 221-50, 260-1.

¹⁴³ For example, the Air Force F-22 is noted for its aggregation of advanced materials, avionics, and propulsion technologies, most of which began life as research in the 1980s. Air Force Association (AFA) Science and Technology Committee, *Shortchanging the Future: Air Force Research and Development Demands Investment*, AFA Special Report (Arlington, VA: Air Force Association, 2000), 3-8, 11, 21, 27.

- Pneumatic tourniquets kit
- Drugs to relieve pain that may be administered by non-medical personnel
- Wound-dressing material impregnated with clotting and antibacterial substances
- Blood substitutes ready for field use (without verification, refrigeration, or preparation)
- Highly mobile oxygen generators
- Miniaturized, reusable monitors of physiological signs
- Portable devices to take vital signs in noisy, unlighted environment
- Mobile and portable imaging equipment

Creating an effective casualty care system that will support the Army of the future requires redirecting medical training, research and development, acquisition, and management to the critical features of the system: Soldiers trained to stop bleeding and aid breathing of a wounded buddy; medics trained and equipped to provide lifesaving trauma care on the battlefield; forward surgical teams trained to practice combat trauma care in small, austere, deployable medical facilities; and aero medical evacuation that provides essential en route patient monitoring and care. Throughout the system design, special attention must be given to procedures for management information systems needed to integrate all patient care activities in the area of operations.

The information revolution and rapid advances in biomedical sciences provide the United States extraordinary opportunity in caring for its soldiers on the future battlefield. It is critical that the Army invest its greatest effort in medical reengineering toward life saving measures at the point of injury. This includes training our soldiers and medics appropriately to handle potential traumas as well as providing them with appropriate equipment.

The process of innovation is of immense social interest and impact, has been studied extensively, and yet remains poorly understood. There is a growing consensus that one important factor in many instances of innovation is the transfer of information and understanding developed in one or more disciplines to other, perhaps very disparate, disciplines. With the explosion in availability of information, scientists and technologists find it increasingly difficult to remain aware of advances within their own general disciplines, much less in other seemingly unrelated disciplines. As science and technology become more specialized, this cross-discipline transfer of information becomes more difficult. To overcome cross-

discipline transmission barriers, systematic methods are required to heighten awareness of discipline experts to advances from other disciplines.¹⁴⁴

Great strides have been made over the past decades in developing trauma systems covering a continuum of pre-hospital, acute care, and rehabilitation services. Public health organizations and providers have embraced the need for a broader, more inclusive philosophy that shifts the focus from the trauma center to a system of trauma care that attends to the needs of all trauma patients over the full course of treatment.¹⁴⁵

Although it is difficult to quantify the total extent of government, community, and private sector endeavors in the injury field, there is a wide range of ongoing efforts, many of which have begun or expanded within the past 20 years. Although the current response is impressive, it is also fragmented. As new injury interventions are developed and evaluated, ongoing information exchange between researchers and practitioners is needed that will facilitate the implementation of new interventions and the refinement of these interventions to meet current and potential future demands. The crosscutting nature of the combat injury problem, as well as of injury research and interventions, has been highlighted throughout this report. Through collaboration and coordination, federal agencies can work jointly to combat related and sometimes overlapping problems and to overcome fragmentation. They can link activities and pool resources, which take the form of expertise, funds, databases, access to patient populations, and technology. They also can avoid unnecessary duplication of effort.

Though civilian organizations have significantly increased their effort to prevent and treat traumatic injury, most of the energy for social action has come from the private sector and through the recruitment of individuals, businesses, foundations, community groups, and other organizations interested in preventing injuries and implementing safety programs. Future advances in the injury field depend on the continued development of the infrastructure of the field through public and private partnerships. The main

¹⁴⁴ Everett Rogers, *Diffusion of Innovations*, New York: Free Press, 1983.

¹⁴⁵ National Research Council. *Injury Control: A Review of the Status and Progress of the Injury Control Program at the Centers for Disease Control*. Washington, DC: National Academy Press, 1988.

challenge seems to be to consolidate the gains that have been made over the past several years and to secure the foundation for further advances in injury science and practice.¹⁴⁶

Areas Requiring Further Research and Analysis

The explosion of advancements in medical technology will certainly usher unintended consequences as well as unforeseen second and third order effects. Many are issues that must be considered immediately to stay on the right path in force development. Every new technology fielded of course requires operator and maintenance training, as well as support devices and tools. Very often such innovations have second and third order effects, such as migration of individual and organizational functions and responsibilities.¹⁴⁷

Innovative medical process and technologies on the battlefield will be no exception to the rule. Organizational understanding and effective integration of medical innovations will require continual training and monitoring to stay abreast of developments. The ever-increasing technical nature of medical care might require more intelligent, more flexible medical support soldiers, or more specialized care providers. Either case implies changes in organization and training, as well as in recruiting and retention processes.¹⁴⁸ Other complications may surface as initial concepts are implemented and tested. More casualties surviving initial trauma will require longer periods of care for recovery as well as immediate resources further rearward through the evacuation system.

Often, regulatory obstacles prohibit rapid implementation of excellent innovations. The Army should examine, and consider lobbying congress for changes in the Federal Drug Administration's (FDA) approval process for drugs and medical devices. The FDA's cumbersome

¹⁴⁶ Ibid.

¹⁴⁷ Shoshana Zuboff, *In the Age of the Smart Machine*, New York: Basic Books Inc, 1988. See also Rogers, *Diffusion of Innovations*.

¹⁴⁸ Notwithstanding the recruiting process might be enhanced through biomedical advances also. Some of the most valuable opportunities arising from genetic and bio-molecular technology innovations could lead to better understanding of individuals' potential capabilities as well as personal desires or inhibitions.

approval process could prevent the Army's use of emerging medical technologies that are well developed and tested, but not yet approved.¹⁴⁹

A host of social, political, and ethical issues will likely accompany these developments. Theological debates have also raised concerns about the definition of what constitutes a human being, since animals and animal material are being modified to produce human blood and organs for use in humans. Improved understanding of human intelligence and cognitive function could have broader legal and social effects. The Army must quickly face this debate with sober consideration and handle emerging complicated issues with consistent policy.

Other, scientific debates in medical care also exist. For example, pre-hospital fluid resuscitation for trauma patients is sometimes a controversial topic in medical care. Although it seems prudent to commence intravenous fluids at the point of injury, some civilian trauma studies have indicated little or no benefit from this intervention.¹⁵⁰ One might argue that initiating fluid replacement only delays evacuation from the point of injury to definitive medical care. It must be recognized however, that studies in civilian settings do not appropriately replicate battlefield injuries, either in the extent of bodily tissue damage or time and distance factors between injury site and a hospital.

Moreover, recognition of these time and distance factors gives rise to further recognition of impending adverse effects resulting from oxygen depletion and starvation in the casualty's tissues. Resuscitative oxygenation cannot reverse damage once cells and tissue begin to die. This controversy must be considered when planning future training for combat medics and Army soldiers as combat lifesavers. If the issue is not definitively resolved, the Army must develop situation based tactics, techniques and procedures. For example, medics could begin fluid resuscitation en route to the next level of medical care, if immediate evacuation is available, or they could start fluids immediately while waiting evacuation.

¹⁴⁹ As shown in Appendix, normal course of development requires more than 7 years for FDA approval.

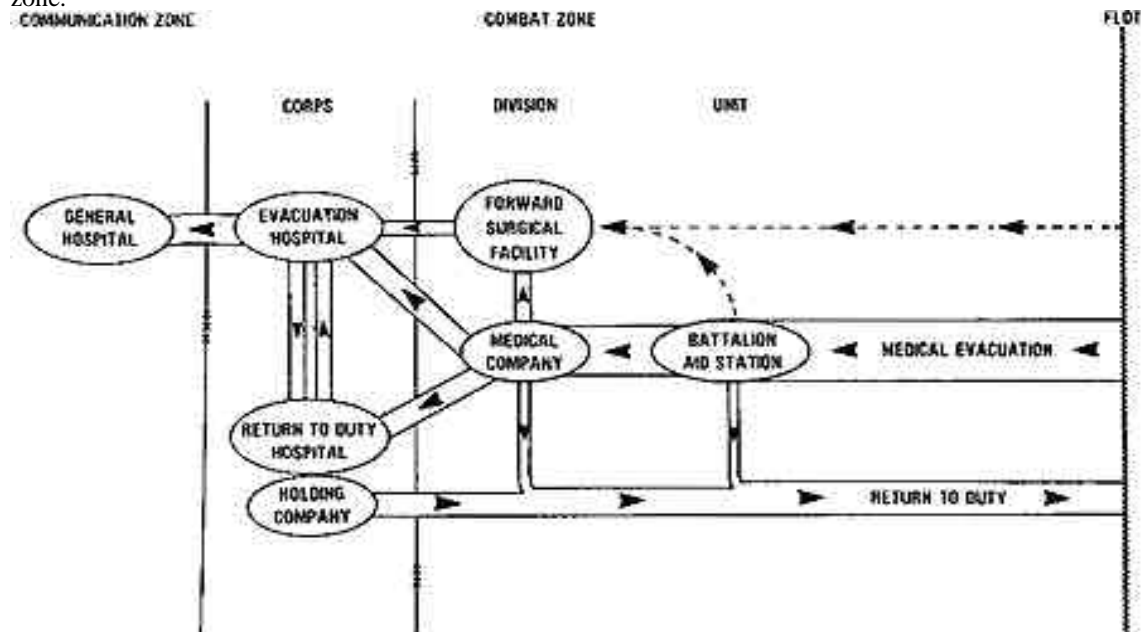
¹⁵⁰ Feero S, Hedges JR, Simmons E, Irwin L. *Does out-of-hospital time affect trauma survival?* American Journal of Emergency Medicine 1995; 13: 133-135. See also, Deakin, CD, Hicks, IR. *AB or ABC: Pre-hospital Fluid Management in Major Trauma.* Journal of Accident and Emergency Medicine 1994; 11: 154-157

Most modern wars do not have a front line and many civilians are hurt. Regardless of the Geneva conventions, there is rarely adequate medical care for wounded noncombatants; first aid and transportation are haphazard. Consistently, the US has provided aid to those noncombatants. Similarly, coalition forces have relied upon the US for logistical and medical support. Both of these situations create additional medical demand that must be considered in force development.

In conclusion, the battlefield is a complex system, and medical care, although quite modular by design, cannot be employed in a “plug and play” fashion without consideration of all other elements of the system. While it is critical to discover and develop these technologies, the United States Army must integrate them effectively into doctrine and allow for innovative tactics, techniques and procedures.

APPENDIX A Care and Evacuation Flow

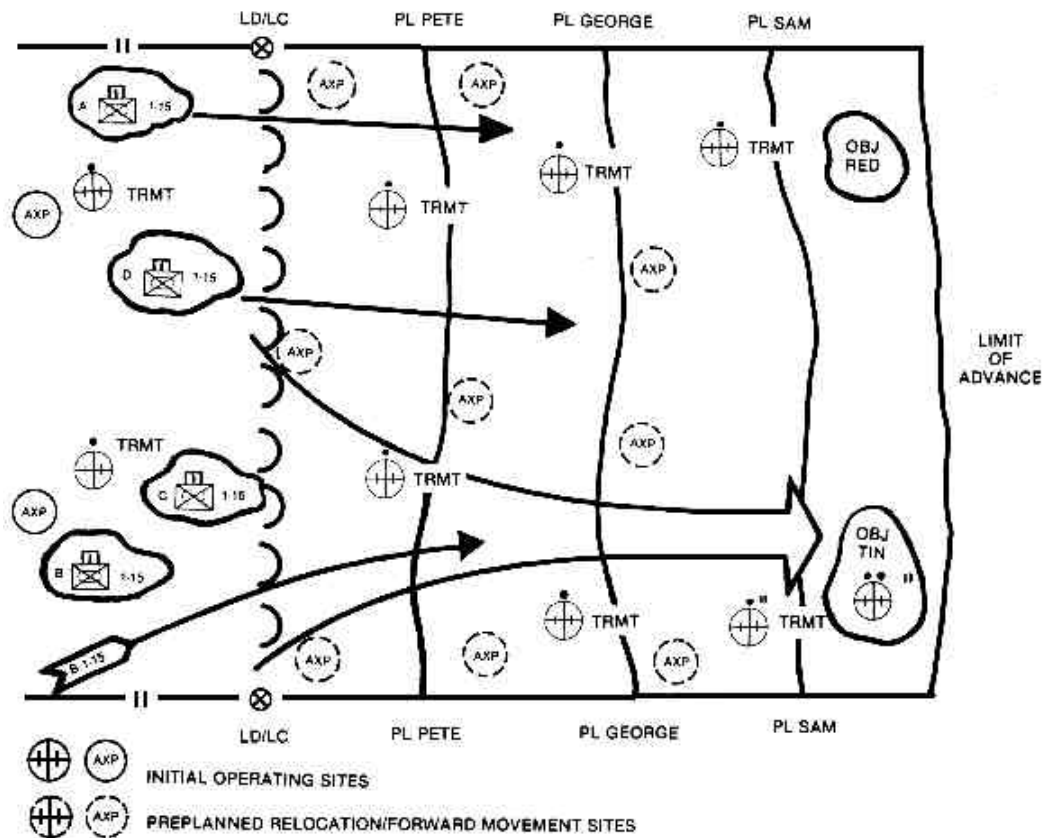
Generic organizational diagram for combat casualty care, and evacuation flow. Width of pathway is proportional to size of casualty populations. Broken line indicates potential for aeromedical evacuation from the field of the critically injured. Triage identifies three groups of casualties: 1) those needing urgent surgery, 2) those likely to have an early return to duty, and 3) those requiring evacuation from the combat zone.¹⁵¹



¹⁵¹ <http://www.vnh.org/EWSurg/Figures/Fig01.html> accessed January, 2002

APPENDIX B Battlefield Layout

This diagram depicts conceptual battlefield layout of medical care capability in current doctrine: Treatment teams and ambulance exchange points.



APPENDIX D FDA Approval Process

Before a pharmaceutical company can begin testing in humans, it must conduct extensive pre-clinical research typically involving years of experiments. The company provides this data to the Food and Drug Administration and requests approval to begin testing the drug in humans.

Clinical testing in humans is usually done in four phases, with each successive phase involving a larger number of people. Phase one studies are primarily concerned with assessing the drug's safety, and phase two with its effectiveness. Phase three involves large-scale testing of the drug for a better understanding of its effectiveness and possible adverse reactions.

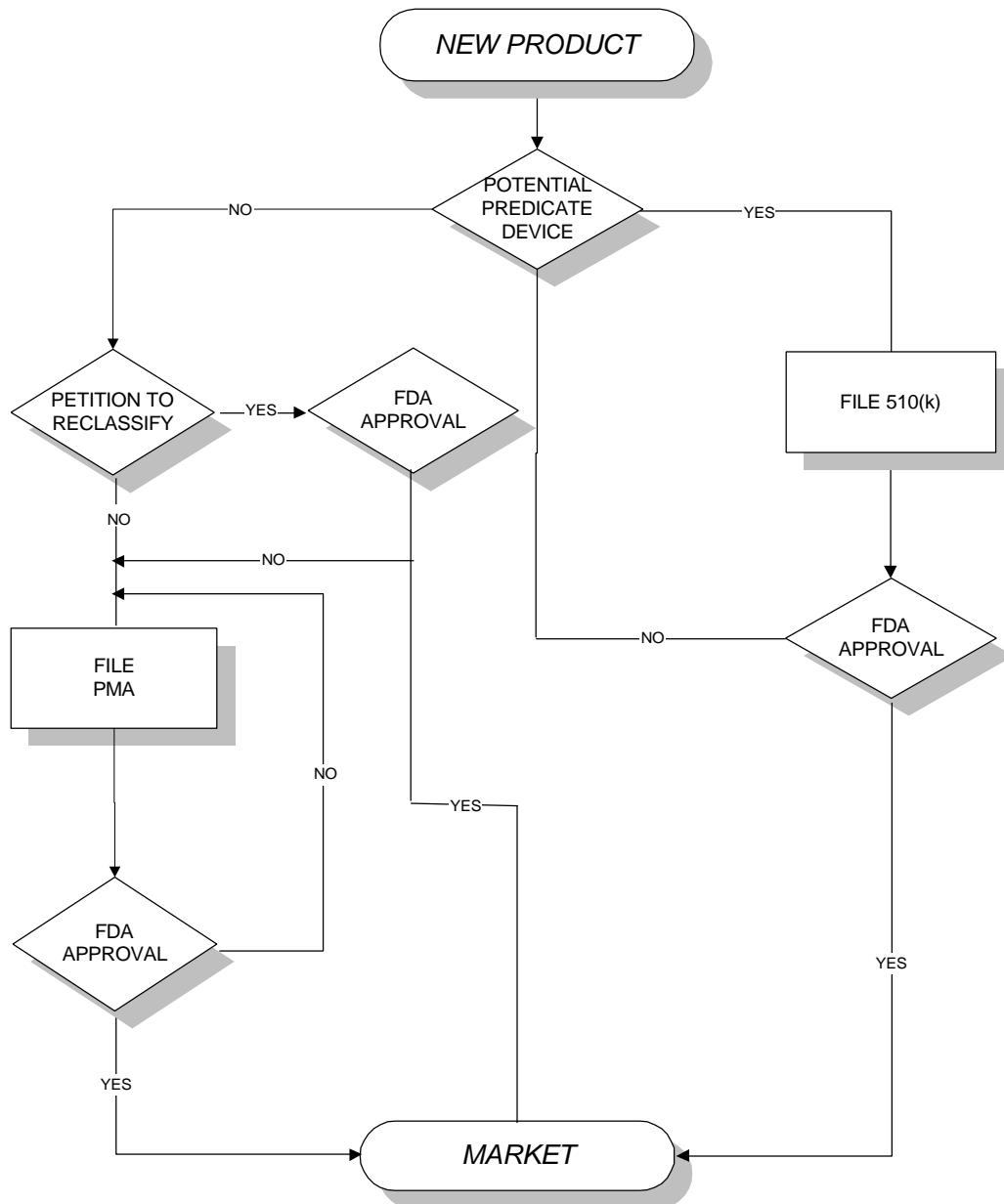
Phase I trials focus on safety and usually involve small samples (20 to 100) of healthy volunteers.

Phase II trials test the efficacy of the drug, usually in studies with dozens or hundreds of patients and often in randomized controlled trials.

Phase III trials test the safety, efficacy, and possible adverse reactions, usually in multi-center, randomized, and blinded trials.

Phase IV studies usually compare the new therapy with the available alternative interventions and determine its long-term effectiveness and side effects and the cost-effectiveness of the interventions

FIGURE 2:
**CURRENT
APPROVAL PROCESS
FOR MEDICAL DEVICES**



Numbers of Americans Killed/Wounded, by Action

Years	Location	Killed	Wounded
1900	China Boxer Rebellion	53	253
1902-1913	Moro Campaigns	130	300
1904	Dominican Republic	1	0
1911-1919	Mexico	19	69
1912	Nicaragua	5	16
1915-1920	Haiti	146	26
1916-1922	Dominican Republic	144	50
1917-1918	World War I	116708	204002
1918-1919	Russia North Expedition	246	307
1918-1920	Russia Siberia Expedition	170	52
1921-1941	China Yangtze Service	5	80
1927-1932	Nicaragua	136	66
1941	North Atlantic Naval War	141	44
1941	Pearl Harbor	2388	--
1941-1945	World War II	408306	670846
1942, Jun 3/7	Midway	307	--
1944	D-Day	4900	--
1945	Iwo Jima	6503	--
1945-1947	Italy Trieste	6	14
1945-1947	China Civil War	12	42
1950	Inchon	670	--
1950-1953	Korean War	54246	103284
1954	Matsu and Quemoy	3	0
1957-1975	<u>Vietnam War</u>	58219 (4)	153356
1958-1984	Lebanon	268	169
1962	Cuba	9	0
1964	Panama Canal Riots	4	85
1965-1966	Dominican Republic	59	174
1966-1969	South Korea	89	131
1967	Israel Attack/USS Liberty	34	171
1968	Tet (Vietnam)	7040	0
1980	Iran Operation Desert One	8	0
1980-1991	Terrorism	28	0
1983	Grenada	19	100
1983-1991	El Salvador	20	0
1984-1989	Honduras	1	28

1986	Libya	2	0
1987 (3)	Persian Gulf	148	467
1989-1990	Panama	40	240
1990-1991	Persian Gulf, Op Desert Shield/Storm	363	357
1991-1992	Somalia, Op Restore Hope	8	--
1993, Feb 26	Terrorism, World Trade Center	6	1000+
1995	Terrorism Oklahoma City	168	400+
1995, Nov 13	Terrorism Riyadh, Saudi Arabia	7	42
1995-2000	Terrorism	77	--
1996, Jun 25	Terroism Khobar Towers, Saudi Arabia	19	500
2000	Yemen, USS Cole	17	651
2001, Sept 11	Flight 93	44	--
2001	Operation Endure Freedom, Afghanistan	4	5 (Friendly Fire)
2002	Operation Endure Freedom, Filipines	12	--
2002	Operation Endure Freedom, Afghanistan Theater	24	28

- (1) Includes Indian scouts, private militia, civillians fighting with Army or Navy
- (2) Adjusted for post war related deaths
- (3) 3 combat, 148 terrorist casualties
- (4) To be adjusted yearly with post combat deaths

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